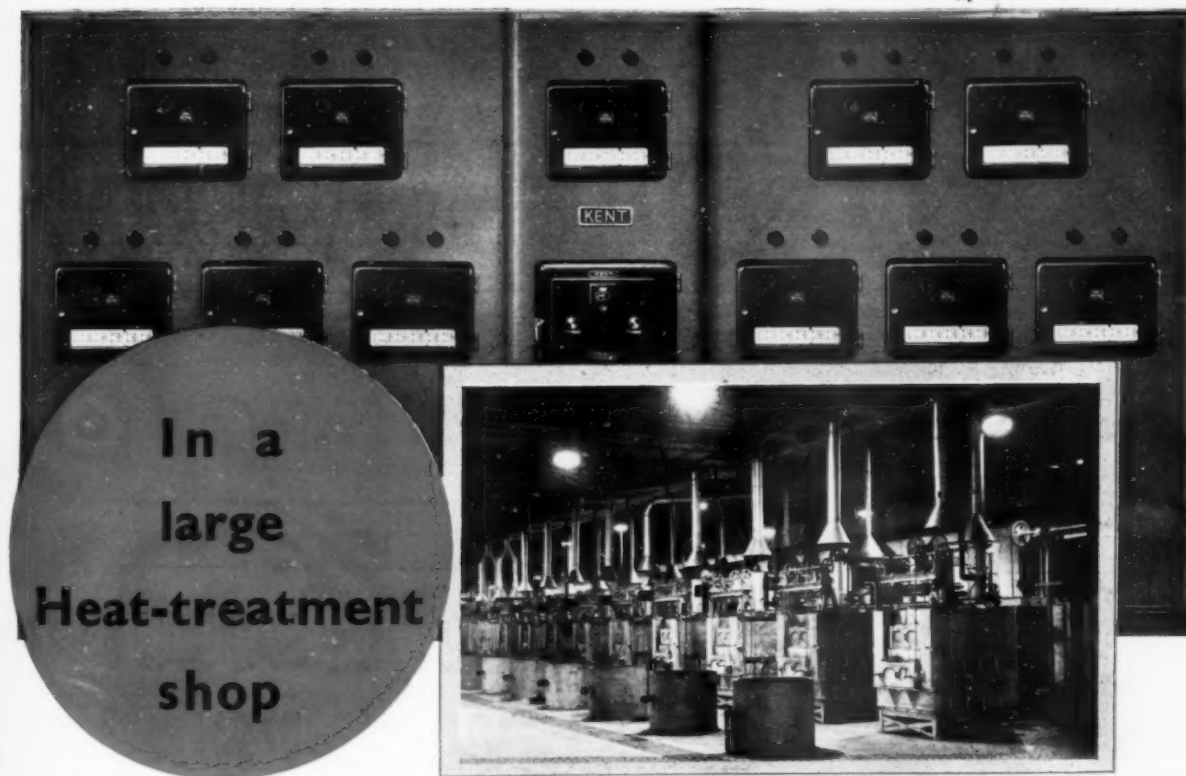


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THE BRITISH JOURNAL OF METALS

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METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

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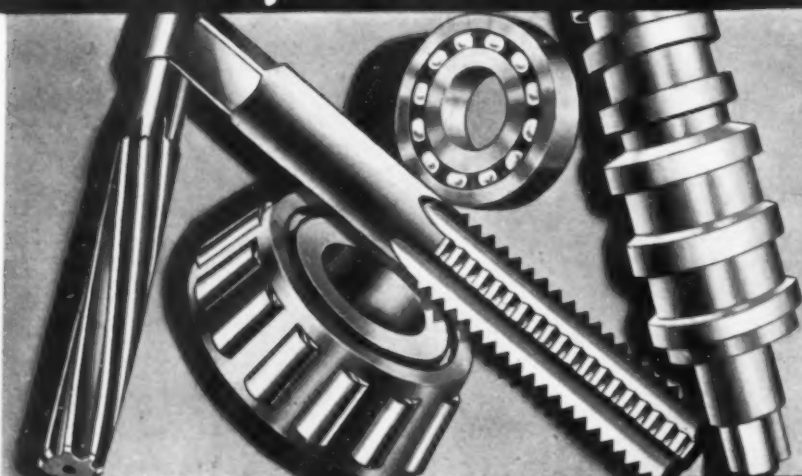
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METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER."

JANUARY, 1941.

VOL. XXIII, No. 135.

Electrical Engineering Progress

British Electrical Industry Continues to Compete in World Markets

In spite of abnormal conditions during the past year the volume of business in most departments of the main British electrical engineering works has been well maintained, and the flow of export orders has been kept up. For obvious reasons, details of a large amount of work carried out during the year cannot be given, but a brief review of some of the work completed and in hand indicates the importance of the contribution being made by this industry under present conditions, and provides evidence of the ability of British industry to compete in the world's markets at a time when production for war purposes is on an unprecedented scale.

AS would be expected, the activities of the main electrical engineering companies in this country have been intensified, and the full power of their vast manufacturing and research organisations have been thrown into the great national effort for production. This has meant, not only a great increase in the output of standard electrical equipment of every kind, but constant attention on the part of designers and research engineers to the problems brought about especially by the war. Apart from the special requirements of the fighting services, which demand first attention, industry, the export market and, in fact, the life of the people generally have introduced problems of a new and special character. Lighting, ventilation and heating are three major subjects which have all claimed attention. It has also been found necessary to review both from the construction and materials point of view the design of products in order to facilitate production and economise in materials. Electrical engineering is so comprehensive in its application to industry that it is only possible here to refer to certain sections, of which not least in importance is power plant.

Power Plant

Although the year has not shown any striking new developments in the design of generating plant, the volume of new business has been highly satisfactory. As far as the larger plant is concerned Metropolitan-Vickers Electrical Co. report that new orders have consisted very largely of repeat orders, and include thirteen complete generating units, ranging in output from 20,000 kw. to 51,500 kw., seven of these for British corporations. Home and export business for smaller plant is also well maintained, and includes numerous industrial units of the self-contained high-pressure and pass-out type.

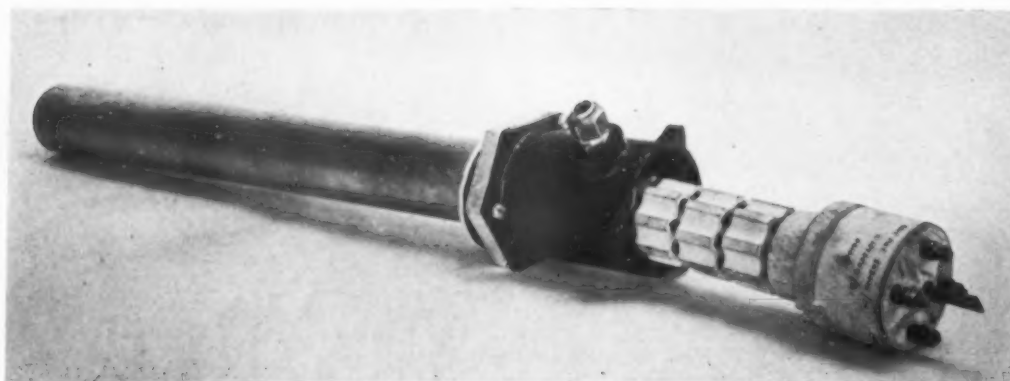
The volume of new export business has been very satisfactory: one of the most important new orders covering a complete power station of 60,000 kw. capacity for Turkey. The turbine plant for this station includes three 20,000 kw. 3,000 r.p.m. turbo-alternator sets, each complete with condenser plant, feed-heating equipment, and auxiliaries. Another important export order is one for a 20,000 kw., 3,000 r.p.m. turbine plant for the China Light and Power Co., in whose station a 12,500 kw. Metrovick unit was recently installed. Several other smaller units have been ordered for China, including a number of sets of the self-contained type. It may be noted that the self-contained design for turbine units ranging from 250 kw. to 6,000 kw. was introduced by Metropolitan-Vickers Electrical Co. in 1928, many being of the pass-out or reducing pressure type.

A large proportion of these units has been installed in the various colonial territories, and will be supplemented by several sets ordered during the year.

Large induction motors, type A 1, continue in popularity, and a number of them have been built or ordered during the year for rolling mills and such applications. It is of special interest that in addition 6,000 h.p. of these motors have been utilised in high-frequency furnace equipments. Other Metrovick orders of interest in this connection are two 5,000 h.p. 1,500 r.p.m. induction motors for driving turbo-compressors, and one 2,600 h.p. 148 r.p.m. mine fan motor with Scherbius control. Numerous synchronous induction motor type A 1 have been supplied or ordered during the year, a large proportion being "inverted"—i.e., rotor-fed.

The General Electric Company report that the overseas demand for generating plant, mercury arc rectifiers, transformers, switchgear and motors reveals great confidence in British-built electric machinery and equipment. As illustrating this demand, motors are being built for various mining companies in South Africa and West Africa; air-cooled pumpless steel-clad rectifiers are in course of construction for towns in India, New Zealand, and Western Australia; switchgear schemes are in hand for an industrial company in Turkey, for railways in India and South America, and also for a South African municipality. A direct-current generator to be driven by a Fraser and Chalmers oil engine is destined for electricity supply in Macao, and turbo-alternators are required for installation in South Africa and India. Undertakings in the Federated Malay States are to be provided with several large transformers and welding plant. High-voltage transformers of considerable outputs will form part of the equipment of large transmission schemes in New Zealand.

The British Thomson-Houston Company report turbo-alternators commissioned during the year for British corporations vary from 16,000 kw. rating to 30,000 kw.; in addition, a 25,000 kw. 3,600 r.p.m. turbo-alternator for a Canadian company has been put into commission. The steam end of this latter machine is a two-cylinder double extraction turbine designed for operation with steam at 800 lb. gauge pressure, 800° F. total temperature, and is direct coupled to an alternator generating at 13,800 volts. Several turbo-alternators are now in course of construction or are completed and being installed; these vary in rating from an 18,750 kw. set for the Brisbane City Council to a 60,000 kw. set for a British corporation. Sets of an aggregate of about 200,000 kw. are included in this category. Recent contracts for British corporations include a 30,000 kw. turbo-alternator, a 20,000 kw. set, and a



An electric heating unit by B.T.H.

15,000 kw. set, while contracts from overseas include a 27,500 kw. set for the Tata Iron and Steel Co., Ltd., of India.

Rolling Mill Motors

Increased activity in the steel industry has led to large orders for rolling mill auxiliary motors. Metropolitan-Vickers Electrical Company has two lines of d.c. steel works motors, each fully standardised, jigged and tooled, the latest line being designed strictly in accordance with the American Iron and Steel Institute's standards. New sizes of these latter machines have been built during the year, with the result that the company can now supply mill motors from 10-150 h.p., strictly interchangeable with motors of American design and rating. During the year the insulation of the d.c. mill motors has been greatly improved by the substitution of woven glass tapes for asbestos tapes. The glass tape, which is made in this country, is more uniform than asbestos tape, and when used in conjunction with the recently introduced synthetic varnishes has greatly improved electrical characteristics. Investigations carried out during the year have demonstrated that machines can now be built to withstand continuous temperatures which are well in excess of 120° C.

Orders have been received during the year for a considerable number of main electrical equipments for mill drives. In connection with these drives numerous steel works' type mill motors have been supplied, both a.c. and d.c. types, but with the d.c. type again predominating. A large number of the equipments have been supplied for non-ferrous drives and others for rolling steel, principally alloy steels. At one plant, for which two reversing non-ferrous mills are on order, each drive is by a 300 h.p. reversing a.c. induction motor. In this case one of the mills is to be entirely automatic in operation; the slab is deposited on the mill table, and when the operator presses the "start" button the mill accelerates for the first pass and then it is held on the back table whilst the screw-down operates. This, when completed, initiates the second pass, and so on until the final pass (may be nine passes in all), when the slab is left on the run-out table, to be removed by operating the inching push-button control of the motor operating that table. In the meantime the screw-down limit switch has reset itself to the roll opening set for pass one, and on the "automatic start" push-button being pressed the mill is set in operation for rolling the next slab. The setting of the screw-down limit switch can be modified for the various requirements at the will of the operator. Provision is made for emergency stopping of the mill and subsequent correct sequence of operations. The second mill is at present hand-operated, but provision is made so that the automatic feature can be added at a later date.

Another interesting non-ferrous strip mill equipment is that of two complete mills each of which consists of three stands which may be worked individually or together. Each stand is driven by a 100 h.p. 900 r.p.m. 300-volt d.c. shunt motor, controlled by a separate 85 kw. 300-volt d.c. generator. This gives utmost flexibility, the field of the generator is controlled by a motor-operated rheostat for

individual control. For tandem control a motor-operated rheostat is provided to control the field of a variable voltage exciter which supplies the generator fields. Thus the voltage of all three mill motors may be varied simultaneously, relative speed differences having been pre-set on the respective generator fields by means of the separate motor-operated rheostats.

Another five equipments of 325 h.p. 0/485 r.p.m. 370-volt reversing d.c. motors, each supplied from separate 260 kw. d.c. generators, have been supplied for driving non-ferrous strip mills. The operation of each mill is from a separate control desk with master controllers and instruments. Contactor control equipment is included throughout, and allows of mill speeds to be pre-selected from the control desk. The normal acceleration and deceleration of the mills is obtained by means of a motor-operated rheostat to obtain smooth and gradual operation. The master controller is arranged to give two automatic speeds in either direction—viz., a "slow" speed for gauging purposes which is fixed and cannot be varied by the operator, and a "fast" or working speed which can be pre-set by the operator and varied by him at will. In addition, any speed below "fast" may be obtained by manipulation of the controller. For inching purposes a second controller is provided that can only be operated when the main controller is in the "off" position and the rheostat has been run back to the "stop" position. It gives two inching speeds in either direction. An emergency push button is provided which de-energises a contactor in the main circuit of the motor so cutting off the supply.

Three of these equipments are supplied from one motor generator set driven by a 1,150 h.p. slip-ring induction motor, and the remaining two from another M.G. driven by a 780 h.p. induction motor.

Of the larger equipments ordered for non-ferrous mills one is for a 780 mm. reversing breaking down mill driven by a 1,350 h.p.—3,150 h.p. 40/51 r.p.m. 450-volt d.c. motor, and supplied from a flywheel motor generator set consisting of a 1,200 kw. d.c. generator driven by a 1,000 h.p. induction motor coupled to a 7½-ton flywheel. The manipulation of the main mill is by means of a drum type controller, making use of the Metropolitan-Vickers Electrical Company's special "compounding" method, which gives completed control of acceleration and deceleration. It also limits peak loads during forward rolling and regenerative peaks when the motor is acting as a generator.

Among the ferrous mills, a 28-in. cogging mill equipment for alloy steels has been ordered, having a mill motor of 3,000-10,000 h.p. 0/55/120 r.p.m. 800 volts, supplied from a flywheel motor-generator set consisting of 2,000 h.p. 6,600 volts, induction motor driving two 1,200 kw. d.c. generators and a flywheel of 150,000 h.p. secs. The control of this mill is the same as that for the 780 mm. breakdown mill referred to above, except that no synchronisation of live rollers is arranged for.

In conjunction with this plant, electrical equipment has been ordered for a 12-in. merchant mill. The motor for this mill is 750 h.p. 500/1,000 r.p.m. 500 volts, and is

geared to the mill. The motor is supplied through a rotary converter. A further order has been received for a reversing motor equipment of 3,750-15,100 h.p. 63.5/170 r.p.m., driven from a flywheel motor-generator set complete with central gear similar to the 3,000 h.p. equipment mentioned above. In this case the induction motor is of 3,000 h.p. and 11,000 volts supply.

Among the tube mill equipments supplied, one of special interest is that required to drive a push-bench equipment with a reversing motor rated 700-1,800 h.p. 300/450 r.p.m. 500 volts d.c. supplied from a motor generator set consisting of 560 kw. 500 volts d.c. generator driven by a 820 h.p. (715 kw. 0.9 P.F.) synchronous induction motor, 5,500 volts, 3-phase, supplied through a Scott-connected transformer from 7,000 volts, 2-phase supply.

Many important orders received by the British Thomson-Houston Company during the year for main rolling mill drives include a complete rod-mill equipment, comprising a d.c. motor rated 1,250 h.p. and two rated 850 h.p., all running at 325/650 r.p.m., and supplied from a 2,000 kw. rotary converter. One order was for a 500 h.p. 360/900 r.p.m. d.c. motor, with motor generator set, for a double duo rolling mill for special steels. Another order covered a 1,500 h.p. 214 r.p.m. slip-ring induction motor for driving an aluminium cold-rolling mill. Frequent starting, stopping and "plugging" of this motor are arranged for by the use of complete contactor control equipment—including high-tension reversing contactors for the stator circuit, similar to those commonly used in electric winder service. To work in conjunction with this motor a coiler drive has been ordered, consisting of a d.c. 100 h.p. motor, with control equipment arranged to start and stop approximately in synchronism with the main induction motor.

From India an order was received for the drive of a 28-in. three-high billet mill, comprising a 2,500 h.p. 750 r.p.m. slip-ring induction motor with control gear. The control gear includes a complete contactor starter and contactor slip regulator, with forward and reverse inching features, and automatic "plugging" for emergency push-button stopping. Another export order received was for a 750 h.p. 500 r.p.m. slip-ring induction motor for driving a sheet-finishing mill in Australia.

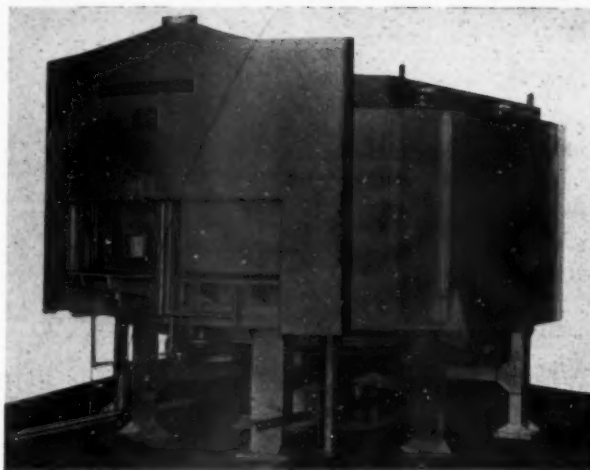
Rolling mill equipments put into service by this company during the year include two reversing mill equipments, each comprising a d.c. reversing motor rated at 1,350 h.p. 40/51 r.p.m., with a peak rating of 3,900 h.p. and receiving its supply from a flywheel motor-generator set; the latter consists of a 1,000 h.p. slip-ring induction motor, a d.c. 1,190 kw. generator, and a flywheel having stored energy of 50,000 h.p. seconds. The installations include all the auxiliary motors and control gear for the reversing mill.

Industrial Heating

The demand for industrial heating has grown considerably during the year, especially in connection with extrusion presses and salt baths. The advantages of electric heating have been particularly appreciated in those cases where gas services have been interrupted. As a result of increasing experience, the practice of using the toribar element with special sheath material has been adopted in place of the heaters previously cast in.

Other industrial heating applications include heat-treatment of brass cartridge cases by the use of electrically heated lead baths, the quenching of light alloy sheets by modified water heaters in quench tanks, and the heating of creosote oil produced in gas works as a substitute fuel for petroleum to be used largely in foundries and glassworks.

There has been a continued increase in the number and type of electrical resistance furnaces installed. This has been due primarily to the more stringent specifications imposed on or adopted by manufacturers. An interesting feature has been the increase in size of electric resistance furnaces. Some of the roller hearth type are in operation, having a length of 200 ft., and are used generally for the bright annealing of cold-rolled steel strip in straight



A rotary hearth electric furnace by the General Electric Co.

lengths, boiler and other tubes (inside and outside) and non-ferrous metals and alloys in sheet and strip.

The vertical cylindrical type furnace has been applied to the stabilising and nitriding of crankshafts with marked success. The cylindrical pots which take the place of the ordinary nitriding boxes have a very simple, quick and effective means of closure and a uniform distribution of ammonia throughout the charge is obtained. Distortion of the crankshafts is reduced and the hardness is very uniform.

Furnaces for the ageing, annealing, and solution treatment and general heat-treatment of aluminium and aluminium alloys in the form of sheet, strip and rolled and extruded sections have been installed, some of them being as long as 65 ft. Other types are the forced air circulation furnaces for low-temperature heat-treatment and for tempering purposes; also high-temperature furnaces for the heat-treatment of special alloys and continuous multi-tubular types for the bright annealing of fine non-ferrous wires.

Much development work has been undertaken in connection with the production of artificial gas atmospheres required for the bright annealing of medium and high-carbon steels which have been rolled or drawn with different lubricants, for the hardening of steel parts without scaling or decarburisation; for the clean hardening of high-speed tool steels; for brazing furnaces, etc.

A new electrode type salt-bath furnace for the hardening of high-speed steel tools has been introduced, and a number have been made for important engineering works in this country and overseas. This furnace represents the latest development in the technique of hardening high-speed steels without scaling or decarburisation. It is also being used very successfully for brazing high-speed steel and tungsten carbide tips on to medium carbon steel shanks.

Heat is generated by the passage of the current through fused salts, which are so compounded as to be neutral. This is an ideal method, since heat is only generated in the place where it is to be used. The normal working temperature range is from 1,100° to 1,350° C. Since all the faces of the work when immersed are in contact with the molten salt, the rate of heating is high, and so is the output of the furnace. Even with small cutters the finish and hardness of the fine edges are unimpaired by heat-treatment in a salt-bath furnace.

Electric Furnace Equipment

A heavy demand for induction furnace equipment has been satisfied this year, attention having been paid in particular to flexibility. Modern requirements generally call for several furnaces to an equipment, any one of which may be connected to the high-frequency supply; thus individual furnaces may be allocated to certain classes of steel, enabling the foundry to supply a wide range of products at short notice.

Hitherto furnace selector switching has been carried out by means of orthodox knife switches, modified slightly on account of frequency, housed in cubicles situated upon the furnace platform and arranged for hand operation. These switches were designed to carry 800 amperes per blade, and comprised anything from 4 to 12 blades. This arrangement resulted in increased lengths of bus-bars, together with not inconsiderable erection difficulties, whilst it was also found difficult to retain the interleaving of the bars which the high frequency demands. A new bus-bar selector switch was developed to overcome these difficulties.

The new switch is of skeleton design and so arranged that only one dimension, the length, varies according to the number of blades it carries. The knife blades carry 800 amperes each and move through only 60° to effect a change from one set of bus-bars to another, and the connections disconnected become earthed automatically. An "off" position is provided midway. The design is such that the switch may be mounted in any position, thus enabling an economical and straight run of interleaved bus-bars to be maintained. Operation is by a fractional horsepower motor, and a full set of auxiliary switches is provided to render the stopping of the motor automatic, to facilitate interlocking with other apparatus, and to give position indication. Control is effected from a simple switch mounted on the furnace-control cubicle, or in any convenient position.

Final Finishing of Tools and Gauges

A new application of great importance in the manufacture of tools and gauges has been found for the Osira black glass lamp. In the process of final finishing, which is usually accomplished by scraping, it is difficult to detect high spots, and it has been found that the older method of coating the surface with jewellers' rouge can be replaced with increased speed and accuracy and without strain to the eyes, by coating the surface with a mixture of powdered anthracene in medicinal paraffin oil, and inspecting the work under the rays of an Osira black glass lamp. In these circumstances high spots fluoresce brilliantly enough to be clearly visible in a normally lighted room.

The Constitution of the Magnesium-rich Alloys in the Systems Magnesium-Lead, Magnesium-Tin, Magnesium-Germanium and Magnesium-Silicon

IN order to examine the effect of compound formation on the form of the liquidus, solidus, and solubility curves, an investigation has been made of the magnesium-rich portions of the equilibrium diagrams of the alloys of magnesium with the elements of Group IVB. The results are discussed by G. V. Raynor* in terms of the theory of magnesium alloys. These results show that the equilibrium diagrams for the magnesium-rich alloys with lead, tin, germanium, and silicon have been investigated. The liquidus curves for the α solid solutions were determined in all four systems, and the α solid-solubility and solidus curves were examined in detail for the alloys with lead and tin. X-ray experiments were carried out to estimate the slight solubilities of germanium and silicon in magnesium.

The solubility of lead in solid magnesium was found to extend to much higher concentrations of lead at high temperatures, and lower concentrations at low temperatures than was previously supposed, while the values of Grube and Vosskühler for the solubility of tin were substantially confirmed. The solubilities of germanium and silicon in magnesium were found to be very slight.

The liquidus curves for the four systems form a clear valency group, with minor differences between them which may be accounted for on general theoretical principles.

The results of the work are discussed in the light of general principles deduced from previous systematic studies of copper, silver, and magnesium alloys, with special reference to the effect of a stable binary compound on the form of the equilibrium diagram.

Jour. Inst. Metals*, Dec. 1940, **40, 12, pp. 403-426.

Magnesium in Aircraft

Its Alloys have Favourable Qualities

THE importance of magnesium and its alloys in aircraft construction is being increasingly appreciated, and application is expanding rapidly. Magnesium alloys are lighter than aluminium alloys and, particularly in the "as cast" condition, are as strong; their use, therefore, effects a reduction in dead weight, which permits an increased carrying capacity for passengers or freight, or, in the case of warplanes, more armaments. Years of research and experimental work were spent before economically valuable alloys were developed and, since their introduction to various sections of industry, improvements in the alloys have resulted from further research. To-day, the rapidly increasing use of magnesium alloys in this country and elsewhere is due largely to one main factor—their favourable qualities for industrial purposes.

Introduced first in Europe then in the United States, the alloys of magnesium under the trade names of Elektron, Magnuminium, Dowmetal, and Mazlo (A.M. Alloy) have now found their place in the aircraft industry, and their applications are constantly on the increase. The properties of magnesium alloys are briefly discussed by Woldman* and a comparison made between some properties of Dowmetal and other metals based on equal volumes. Characteristic uses of castings of various magnesium alloys are given, wrought alloys are also considered. Some attention is devoted to the question of corrosion of these alloys and its prevention. Reference is made to chemical methods of surface treating magnesium alloys, which include the chrome pickle treatment, the dichromate treatment, modified alkali chromate treatment, galvanic anodic treatment, and the sealed chrome pickle treatment. The present applications of magnesium alloys in aircraft are given under the forms in which the alloys are marketed and, as these show how widely they are entering this industry, they are reproduced in the following lists.

Sheets, bars, extrusions: Doors, hatches, floors, seats, instrument assembly panels, partitions, air ducts, furniture and secondary structures. Sheets are used extensively in the construction of fuel tanks, oil tanks, cowling and fairing. The main spars of the 12-engined flying boat, the Do-X, were made of extruded magnesium alloy.

Forgings: Propeller blades, supercharger impellers, engine pistons, engine crankcases, engine nose sections, supercharger rollers.

Castings: These are given in three categories—permanent mould castings, such as landing wheels; die castings like engine rocker box covers and shroud tube fittings; and sand castings, the latter showing a wide range of applications including engine crankcases, gear cases and covers, engine nose actions, tail wheel assembly parts, brake assemblies, starter housings, pump housing, intake manifolds, oil sumps, supercharger rollers, hydraulic pump bodies, thrust bearing housings, diffuser plates, camshaft housings, generator housings, window frames, pedals, wheels, tail forks, deicer pumps, blower sections, engine rear sections, automatic pilots, distributors, instrument cases and parts, control column parts, rear and front supercharger sections.

Personal

MANY readers will join us in expressing our congratulations to Mr. Allan John Grant, Managing Director of Thos. Firth and John Brown, Ltd., and member of the Board of John Brown and Company, Ltd., and to Mr. Samuel Osborn, J.P., Chairman of Samuel Osborn and Company, Ltd., on their inclusion in the New Year's Honours List. The conferment of knighthood upon Mr. Grant by H.M. the King at the works of Thos. Firth and John Brown, Ltd., was an unusual honour.

* Dr. N. E. Woldman, *Metals and Alloys*, Vol. 12, No. 4, 1940, pp. 430-5.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Looking Ahead

UNDER normal conditions looking ahead had become a necessity; the injunction to "take no thought for to-morrow" did not take into consideration the material welfare of peoples and nations, for which preparation is essential to their well-being. It is a natural pre-occupation of all people of vision, and must be given practical effect by preparation. In normal peace-time activities future success depends almost entirely on the expertness of vision and preparation which have been applied in advance, but under such conditions the course of events can be regarded with some degree of certainty, which simplifies and assists in facilitating looking ahead. At the present time, though we can be certain of our ultimate victory, there must be a feeling of uncertainty regarding the subsequent course of events, with the consequent reluctance to look ahead. Yet if there is a necessity to look ahead in normal times, the need must be greater in abnormal times, and at this time of emergency it is not too much to say that the future of our country depends upon all its resources not only of experience and experiment, but of outlook and vision.

The intensity of our present concentration upon the specialised war efforts must be increased by the mobilisation of the nation's man-power. This is probably the most important task for this year. Our aims should be a bigger Navy, further additions to the Army, and a considerably increased Air Force, and, to support these Services, the industrial army must be expanded to produce, in ever-increasing quantities, the weapons and materials of war. The Government's policy in steadily building up the fighting forces and the industrial army during last year is commendable; a monthly average of over 50,000 was absorbed by industry, and these are mainly employed in the war effort, yet thousands more are required and half a million are now being enrolled for training in Government centres, technical schools, and factories. Modifications will need to be made in the reserved classes of workers to ensure that adequate man-power will be available to meet the need for further concentration on important war work. Supplementary to this is the setting up by the Ministry of Labour of an international labour branch as an agency to make the best use of the labour of friendly aliens in this country. It is computed that over 100,000 Poles, Czechoslovakians, Norwegians, Dutch, Belgians, Frenchmen, and many thousands of Austrian and German refugees from Nazi oppression, are in this country, the majority of whom will be only too willing to contribute their energies in the present emergency.

Although the war effort must be carried on with increasing intensity and the nation's man-power so directed that it is 100% in the national interest, the hopes of all are that an early satisfactory conclusion to hostilities will be realised, and we must plan for a prolonged commercial effort which can be given effect immediately activities cease to be directed to the successful prosecution of the war. Many display a certain reluctance even to consider the future, maintaining that the present is absorbing all their energies, and while this is understandable to some degree, prepara-

tion for peace will present as many problems as preparation for war. It must be remembered that we were unprepared for war when hostilities commenced, and full mobilisation of the nation's man-power for war purposes has not yet been achieved. Obviously lack of preparation placed the nation and the whole British Commonwealth in great danger at a most critical time. The conclusion of hostilities will be not less critical for this country, and however intense the present concentration upon the specialised war efforts, it should not blind us to the future.

If we have learnt the lessons of the post-war period of the last war our resources of outlook and vision will not allow the present war efforts to interfere with the future of the various industries upon which the prosperity of the country depends, but rather these momentous days, and greatly altered methods, will be used to reshape various practices to the common good. Changing over from the production of destructive weapons to the manufacture of machinery and goods for use is not the simple operation it may seem; it is no more simple than the changing over, experienced by so many, to war work, but it is noteworthy that the amount of skill available will have increased enormously in certain sections as a result of the war, and to this extent our ability to produce need not have been greatly diminished; it may in fact have been increased. We can be certain, however, that changes will, in time, greatly affect each section of industry, and while these changes cannot be foreseen, we can take a lead from indications of the present with a view to reshaping our attitude to the future.

Once we have completed our immediate task we shall realise that the end of the war will not have brought about the condition we regarded as normal in peace-time. Whatever may be the outcome of the war, at its close we will face a new world and it will be necessary to plan reconstruction exactly as war production ought to be planned. A system of Government controls will be just as necessary to enable the nation to throw its whole strength into the peace effort. There will be the same need for the control of man-power in order that it can be directed into useful and profitable channels from a national rather than a personal point of view. Complete freedom immediately after the war should be no more possible than during the period of hostilities, otherwise the few will profit at the expense of the many in the world's need of reconstruction, and similar conditions which followed the last war will return. Demobilisation of the Forces must take place accordingly as work is provided. Our methods must be elastic enough to include the new factors which will be presented and the supply of materials will need to be adjusted according to the importance of the work in the scheme of reconstruction.

How long Government control of peace-time activities should remain it would be idle to prophesy, but in order to effect ordered progress, it seems essential at the outset, although doubtless as more normal conditions are resumed, control would tend to be gradually released. Certainly the flux of events will present new problems, and to meet these Britain will need all her resources of experience and experiment, and of outlook and vision.

May we take this opportunity of expressing the wish that readers will be able to regard 1941 as a happier year than 1940; that before the year is out it may be possible to concentrate activities on progress and reconstruction.

New Synthetic Resins in Abrasive Wheel Fabrication

THE older synthetic resins, notably of the phenol-formaldehyde (bakelite) and furfural types, have long been used as the bonding agent for abrasive granules by makers of cutting discs and like equipment. As new synthetic resins emerge from the laboratory stage and enter the commercial field, the possibility of applying them as abrasive bonders will not unnaturally be borne in mind.

The distinctive properties of some of the newer resins have aroused considerable interest from this aspect, and the performance obtained from wheels bonded with the new materials have been highly encouraging. In the long run the data obtained from tests on the bonding properties of a wide range of synthetic resins (not to mention the plastics derived from cellulose) are bound to raise the standard of efficiency of abrasive wheels. Long dependent upon such natural bonding agents as rubber and shellac, the abrasive wheel industry can now make its choice from numerous synthetic materials, confident that one or the other will provide the qualities lacking in the natural products. Of the resins appearing on the market within comparatively recent times, brief mention will here be made of two types: the methyl methacrylate polymers and the melamine-formaldehyde resins, the former in the thermoplastic and the latter in the thermosetting category.

With a transparency surpassing that of ordinary glass, the polymethyl methacrylate resins, on which much of the development work was carried out in British laboratories, have found extensive application in many branches of the plastics industry. For the special requirements of an abrasive-bonding resin the best results have been obtained with the so-called copolymerised methyl methacrylates, the process consisting essentially in mixing liquid methyl methacrylate with another polymerizable liquid of related chemical structure. The glass-like solid ultimately formed from this mixture is found to be superior to polymethyl methacrylate itself in such important qualities as high-temperature resistance and toughness.

Particularly good results have been obtained¹ with resins formed by copolymerisation of methyl methacrylate with substances such as ethylene glycol dimethacrylate and allyl methacrylate. The mixed liquids in which a trace of benzoyl peroxide is present as polymerisation catalyst are poured in suitable proportion over the abrasive granules (garnet, quartz, boron carbide, etc.) in a suitably dimensioned mould with a plug for the central hole. By baking for some hours at the correct temperature the hardening of the resin and the agglomeration of the abrasive are simultaneously effected. Polymerisation of the liquid mixture may also be conducted independently, the final resin (powdered) being then mixed with the granules before moulding and baking.

Melamine-formaldehyde resins were pioneered largely by the Swiss chemical industry, which solved the problem of cheap production of melamine (previously a rare chemical) from calcium carbide, an achievement which, incidentally, illustrates once again the importance of calcium carbide production to a progressive industrial community. With their glass-like clarity (unaffected by sunlight), infusibility and chemical inertness, the melamine-formaldehyde resins may be regarded as a stage in the continuous improvement in quality of thermosetting resins, the earlier landmarks in which were the phenol-formaldehyde and the urea-formaldehyde resins.

At present the melamine formaldehydes are undergoing active development on the continent and in the United States as components of many plastics, varnishes, printing inks and the like. They have also been studied from the special angle of the abrasive wheel-maker. Cohesion of the abrasive granules is found to be improved if they are first wetted with 5 to 25% of an agent such as ethylene glycol

monoformate.² The wetted granules are then well mixed with 10% by weight of a liquid melamine-formaldehyde resin containing a trace of hardening catalyst (phosphoric acid). A free-flowing powder is thus obtained which is finally moulded to the required size and shape by hot-pressing and the wheel finally cured for several hours at 110° C. or higher. Used on these lines as abrasive binders, the melamine-formaldehydes may be said to combine the high-temperature stability of the phenol-formaldehydes with their own great inherent toughness and water-resistance.

Forthcoming Meetings

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Jan. 21. "Heat-treatment of Alloys," by Prof. D. Hanson, D.Sc.

Feb. 6. "Spectroscopic Analysis," by F. Twyman, F.R.S.
MANCHESTER METALLURGICAL SOCIETY.

Feb. 5. "Magnetic Materials," by D. A. Oliver, M.Sc.

NORTH-EAST COAST INSTITUTION OF ENGINEERS
AND SHIPBUILDERS.

Jan. 31. "Effect of Some External Factors on the Performance of Single-screw Ships," by A. Karl, M.Sc.

Feb. 14. "Ships' Cargo Handling Gear," by Leslie T. Morton, B.Sc.

INSTITUTE OF BRITISH FOUNDRYMEN.

EAST MIDLANDS BRANCH.

Jan. 25. "Coreshop Production Costs," by N. P. Newham.

SCOTTISH BRANCH.

Feb. 8. "The Making of Rope Pulleys," by John F. Webster.

Correspondence

The Use of Aluminium Scrap

To the Editor, METALLURGIA.

Sir,—We are in complete agreement with the official decision respecting the segregation of aluminium scrap, for this has long been an established practice in the secondary metals industry, at least with those firms producing specification alloys.

While generally endorsing the views expressed by Mr. H. J. James, we cannot agree with the statement that, prior to the War, scrap, such as sheet cuttings, etc., was chiefly used in the manufacture of low-grade casting alloys. This is scarcely fair to the secondary metals industry, and, in particular, to the technical and research departments of the firms producing the highest grade alloys.

We ourselves have, over a long period of years, produced from this type of scrap, every proprietary B.S.S. and D.T.D. specification alloy issued, with margins of safety for both chemical and physical properties.

Official recognition of the possibilities of the proper use of scrap aluminium is indeed most gratifying to the whole of the secondary metals industry.

Yours faithfully,

R. T. PRIESTMAN,

Governing Director, T. J. Priestman Ltd.

Birmingham,

Dec. 27, 1940.

Sir,—I still maintain that before the War the bulk of wrought aluminium alloy scrap was converted into casting alloys of relatively low grade. In this connection I would mention that in my statement I took particular care to qualify "low grade" by the adverb "relatively."

It is difficult for me to see the purport of Mr. Priestman's letter, particularly as his Company probably did not handle much more than 10% of the aluminium scrap coming on to the market before the war.

Yours faithfully,

H. J. JAMES,

Director, Northern Aluminium Co., Ltd.

Banbury,

Jan. 11, 1941.

¹ U.S.P. 2,189,733-5, The Norton Company.

² U.S.P. 2,200,164, American Cyanamid Company.

The Hardness Testing of Micro-specimens, Micro-constituents, and Minerals

By Hugh O'Neill, M.Met., D.Sc.

Hardness testing by micro-indentation has made considerable progress in recent years; its utility lies in the possibility of examining metallic foils, very thin plated and treated surfaces, individual constituents in microstructures and even enamels, ceramics and minerals. In this article certain of these developments are outlined and reports are given of some of the results obtained.

CERTAIN recent developments in the technique of hardness measurement have been concerned with the utilisation of minute indenters to permit of the examination of very small specimens. This aspect of the subject is frequently referred to as micro-hardness testing, but objection may be raised to the term on the grounds that the hardness values involved are not necessarily very small, nor are measurements with a microscope more particularly necessary than in ordinary practice. It is therefore more accurate to describe these developments as hardness testing by micro-indentation, and their utility lies in the possibility of examining metallic foils, very thin plated and treated surfaces, individual constituents in microstructures and even enamels, ceramics and minerals. The present article outlines these specialised methods and reports some of the results obtained. Furthermore, since the diamond pyramid hardness scale is becoming more and more recognised as the best standard of reference, an attempt has been made to refer all these results to this scale.

The instruments which first lent themselves to applications of the kind under consideration were scratch testers. Methods which depend upon the determination of the production or non-production of a scratch, generally prove rather difficult in operation. On glass, for instance, at least three types of visible scratch may be described. Bailey¹ recognises both "surface abrasions" which do not affect the mechanical strength of the glass, and "surface crushes" which do. The latter are true scratches whereby a groove is made and material is removed from the surface and they enable materials to be classified according to the Mohs hardness scale. The third type is called "chatter-sleek" scratches by Ghering and Turnbull², and these reduce the mechanical strength of the glass whilst producing a series of percussion crescents within it. No glass is removed, however, but traces of the scratching material remain behind adhering to the parent plate. With this type of deformation it is possible for zinc, aluminium and copper to produce visible markings on glass, though tin, lead and magnesium are without permanent effect.

Considering the indeterminate nature of the scratch-making process, the most desirable method is to produce real scratches with a hard indenter and then measure their width. This procedure seems satisfactory to the mineralogists, and Gehlhoff and Thomas³ have published studies showing the way in which the hardness of glass increases when silica is replaced by ZnO or BaO, and decreases with K₂O and Na₂O. Metallurgists find that trouble still arises because of the irregular edges of the scratch furrows, and have turned their attention more to the production of micro-indentations by refined static loading methods and diamond indenters. Some types of instrument available for work of this kind are given in Table I.

For ease of location of the micro-indentations it is obviously desirable that the measuring microscope shall be associated with the indenting system. In the Lips instrument the indenter consists of a detachable nose piece

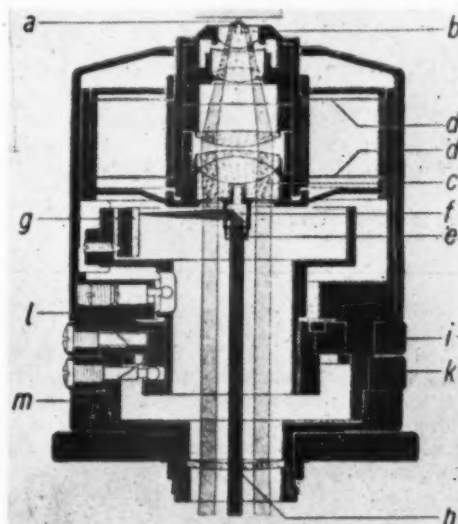


Fig. 1.—Zeiss micro-indenter and objective. (a) Diamond pyramid, (b) front lens, (c) back lens, (d) disc ring springs, (e) auxiliary objective, (f) mirror, (g) load scale, (h) correcting lens, (i) (k) knurled setting rings, (l) eccentric for sharp focusing, (m) unit of zero-point focusing.

applied to an ordinary microscope, the load being applied by racking down the main tube against a calibrated spring. As a development of this the Zeiss tester (No. 10) has a small diamond pyramid 0.8 mm. wide fixed to the actual front lens (2.3 mm. diameter) of the special "objective" of a microscope as shown in Fig. 1. This remarkable component consists of a bottom part fixed by two parallel disc ring springs to an upper part. Screwing down the main tube so that the indenter presses into the test specimen causes a deformation of the disc springs which is registered by means of an auxiliary self-contained objective on to an internal scale. The image of the scale moves within the eyepiece by an amount which is a measure of the load exerted on the diamond, and the scale itself may be pre-set to the desired load by adjustment of an external ring. A special type of eyepiece is used for measuring the impression so that the testing operation first consists of lowering the indenter until the loading system reaches the desired value as viewed in the eyepiece, after which the apparatus is refocused and the size of the indentation measured. It is claimed that the selection of the spot for the impression can be made with an accuracy of 10–50 microns, and this permits of the testing of micro-constituents as shown in Fig. 2. Furthermore, the machine gives good results on minerals.

The Knoop micro-indenter (No. 9) uses a pyramidal diamond giving a rhombic indentation, resembling somewhat the pyramidal steel indenter devised by Rodman¹⁴ in 1861. Elastic recovery of these indentations takes place

¹ J. Bailey, *J. Amer. Ceramic Soc.*, 1937, 20, 42.

² L. G. Ghering and J. C. Turnbull, *Bull. Amer. Ceramic Soc.*, 1940, 19, 290.

³ G. Gehlhoff and M. Thomas, *The Glass Industry*, 1929, 10, 140.

¹⁴ T. S. Rodman; see "Materials of Construction," Johnson, 381

TABLE I.
MICRO-INDENTATION TESTERS.

Ref.	Name.	Introduced by	Indenter.	Load-grammes.	Principle.
1	Marten's sclerometer.	Martens ³ (1890)	90° diamond cone	20-40	Measure scratch width.
2	Micro-sclerometer.	Jagger ⁴ (1897)	Tetragonal diamond point.	10	No. of rotations to drill a standard hole.
3	Sclerometer.	O'Neill ⁵ (1928)	1/2 mm. or 1 mm. diamond ball, or 120° diamond cone, replaceable by microscope.	65-2,000	Scratching or static indentation.
4	Pomey cone test.	Pomey and Voulet ¹² (1929)	136° diamond cone, replaceable by microscope.	—	Static indentation.
5	Micro-character.	Bierbaum ⁶ (1920)	Corner of diamond cube attached to stage of microscope.	3	Measure scratch width.
6	Lips' micro-indenter.	Lips and Sack ⁷ (1936)	136° diamond pyramid attached to microscope.	33	Measure indentation.
7	"Diritest" or Zeiss scratch tester.	Sporkert ⁸ (1937)	120° diamond cone.	—	Measurement of scratch width.
8	Schopper's micro-hardness.	Dühmer ⁹ (1939)	Diamond pyramid attached to microscope.	50	Measure indentation.
9	Knoop micro-indenter.	Knoop ¹⁰ (1939)	Rhombic diamond pyramid, diagonals ratio 7:1.	50-4,000	Measure indentation.
10	Zeiss micro-hardness tester.	Hanemann ¹¹ and Bernhardt (1940)	136° diamond pyramid attached to lens of microscope.	0.2-100	Measure indentation.

in a transverse rather than a longitudinal direction, and consequently from the measured length of the long diagonal and the constants of the indenter, unrecovered dimensions of an indentation are obtained. This particular pyramid is spoken of as being sensitive, and the results are expressed as applied load divided by the unrecovered projected area in sq. mm. From published results it is evident that up to a standard diamond pyramid hardness of about 500, the Knoop values agree well with the standard diamond scale, but at $H_D 900$ they are about 10% low. From the few comparative values at present available and given in Table II, there is an indication that the Zeiss micro test gives results which are about twice those obtained on the standard diamond pyramid scale.

TABLE II.
COMPARISON OF PYRAMID MICRO-INDENTING MACHINES ON MICRO-CONSTITUENTS.

	Knoop ¹⁰ .	Hanemann and Bernhardt ¹¹ .	Lips and Sack ⁷ .
Silicon carbide	2,000	—	—
CARBORUNDUM—			
Sectioned grains	—	7,300	—
Bond	—	1,450	—
CuAl ₂	—	780	395
Martensite, 0.3% carbon	($H_D 900$ —Table 7)	1,500	865
Tungsten-molybdenum carbide	1,160	3,300	—
Solid solution Al + 6% Cu ..	—	81-115	—

A remarkable feature of the Knoop tester is that for the first time the hardness of diamond has been measured, and the pressures involved reach about 12 million lb. per sq. in. It has thus been possible to establish diamond pyramid hardness values for the Mohs mineral scale, and the collected results are given in Table III. The lack of balance in this scale has prompted Ridgway¹⁸ to advocate an extension into sub-divisions beyond mineral No. 6. By making scratches on various materials with the 120° diamond point at various loads, their relative order of hardness suggested the scheme reported in Table IV.

3 A. Martens, *Mitt. K.K. Techn. Vers. Anst.*, 1890, 8, 215; see also G. Richter, *Zeit. f. Metallkunde*, 1937, 29, 355.

4 T. A. Jagger, *Am. J. of Science*, 1897, 4, 399.

5 H. O'Neill, "The Hardness of Metals and Its Measurement," London, 1928.

6 C. Bierbaum, *T.A.I.M.E.*, 1923, 69, 972.

7 E. Lips and Sack, *Nature*, Aug. 22, 1936; *Zeit. f. Metallkunde*, 1937, 29, 339.

8 K. Sporkert, *Metallwirtschaft*, Aug. 29, 1937; *Maschinenbau Betrieb*, 1938, 17, 527.

9 P. Dühmer, *Werkstofftechnik*, 1939, 33, 357.

10 F. Knoop, C. Peters and W. Emerson, *U.S. J. of Research*, 1939, 23, 39.

11 H. Hanemann and E. Bernhardt, *Zeit. f. Metallkunde*, 1940, 32, 35.

12 J. Pomey and P. Voulet, *Rev. de Metallurgie*, 1929, 26, 238.

18 Ridgway, Ballard and Bailey, *T. Electrochem. Soc.*, 1933, 63, 369.

Fig. 2.—Indentation tests on microstructure. $\times 400$ TABLE III.
THE MOHS SCALE AND THE HARDNESS OF ITS MINERALS.

Mohs Scale.		Working Scale. ⁶	Knoop Diamond Hardness ¹⁰ Kilog./sq. mm.	136° Diamond Cone Test, ¹² Kilog./sq. mm.	Scratch Hardness by Bierbaum Micro-Sclerometer, ¹⁵	Drilling Hardness by Jagger Micro-Sclerometer, ⁴
No.	Mineral.					
1	Talc	Very easily scratched by finger nail and greasy to feel by hand.	3	—	1	—
2	Gypsum ...	Easily scratched by finger nail.	32	22	11	0.04
3	Calcite	Scratched by brass pin or copper coin.	135	82	129	0.3
4	Fluorite	Easily scratched by knife.	163	150	143	0.8
5	Apatite	Scratched with difficulty by knife.	360-430	266	577	1.2
6	Orthoclase ..	Easily scratched by file.	560	415	975	23
7	Quartz	But little touched by file, but will scratch window glass; above No. 7 will scratch window glass.	750	584	2,700	40
8	Topas	—	1,250	—	3,420	152
9	Corundum ..	—	—	—	5,300	1,000
10	Diamond ..	—	8,300	—	—	—

⁶From Lange's "Handbook of Chemistry, 1939," which also gives the Mohs hardness of most minerals and compounds. A very complete reference is "Tables of Specific Gravity and Hardnesses for use in the Determination of Minerals," by J. L. Rosenholts and D. T. Smith, Reusseler Polytechnic Inst. Eng. and Science, Series No. 34, 1931, Troy, New York.

TABLE IV.
PROPOSED EXTENSION OF MOHS SCALE.

Mohs Scale.		Proposed Extension. (Ridgway)	Metal Equivalent.	Rockwell Hardness.	Suggested Standard Diamond Pyramid Hardness (Author).
No.	Mineral.				
6	Orthoclase ...	—	—	—	550
7	Quartz	7—Vitreous pure silicon	—	—	625
8	Topas	8—Quartz	Stellite	A79	680
		9—Topas	—	—	750
		10—Garnet	—	—	800
		11—Fused silica	TaC	A82	850
9	Corundum	12—Fused alumina	WC	A87	1,200
		13—Silicon carbide	—	—	1,800
		14—Boron carbide	—	A92.5	2,000
10	Diamond	15—Diamond	—	—	7,500

Ridgway and his collaborators have also studied these various hard materials as regards impact abrasion, using a Zeiss standard sandblast machine with plate-glass as a unit of reference. The number of blasts to give a standard hole 1 mm. deep is determined, and it is interesting to note that soft manganese steel ($H_D=210$) has an abrasion hardness of 230 compared with 180 for hard carbon steel ($H_D=950$), and 600 for tungsten carbide.

The great range over which indentation testing may now be applied is evident from Table V, compiled from various sources. Whereas the diamond hardness scale is rather crowded with examples up to values of 1,000, it becomes extremely rarefied over the great remaining interval extending to diamond. It is not unlikely that this region

15 H. C. Hodge and J. H. McKay, *Amer. Mineralogist*, 1934, 19.

TABLE V.
MINERALS, GLASSES, ETC. (See also Table III.)

Material.	Scratch Hardness.	Rockwell Test.	Diamond Cone Test.	Knoop ¹⁶ Test.	Representative Diamond Pyramid Hardness, Kilog./mm ² .
Plasticine.....	—	—	—	—	0-02
Pitch.....	—	—	—	—	5
Celluloid.....	—	—	—	—	14-5
GRAPHITE—					
Grain size ..	Mohs 1	—	—	—	3
50 x 10 ⁻⁷	—	—	—	—	—
Grain size ..	" 9	—	—	—	2,000
9 x 10 ⁻⁷	—	—	—	—	—
PENCIL GRAPHITE ¹⁷ —		Relative loss by wear at 5 lb./sq. in.			
Maker X H	—	1	—	—	22
HB	—	3-6	—	—	17
B	—	4-6	—	—	10-1
BB	—	9-8	—	—	9-8
Maker Y H	—	0-9	—	—	22
HR	—	4-2	—	—	18
B	—	4-9	—	—	15
BB	—	12-5	—	—	10
Rock Salt ..	25 (Martens)	—	18	—	15
COAL ¹⁸ —					
Anthracite ..	—	—	57	—	40
Vitrinite ..	—	—	17	—	22
Durain ..	—	—	23	—	21
Cannel ..	—	—	17	—	22
Fused quartz ..	—	—	—	475	475
Flint glass ..	—	—	—	180-390	400
Crown glass ..	—	—	—	420-470	450
Albite ..	—	—	—	490	500
Emerald ..	—	—	1,150	—	1,000
Fused silica ..	—	A 82	—	—	850
Fused alumina ..	—	A 87	—	—	1,200
Aluminum ..	—	—	—	1,635	1,450

¹⁶L.M.S. Research Laboratory.TABLE VI.
CARBIDES AND CONSTITUENTS.

	Brinell No.	Rockwell.	Diamond Pyramid.		
			Lips and Sack.	Knoop.	Suggested H _D .
CuAu—slowly cooled	125	—	—	—	130
quenched	110	—	—	—	115
Cu ₃ Al—slowly cooled	45	—	—	—	45
quenched	60	—	—	—	60
Cu + 4% BERYLLIUM					
MEAN H _D —					
Cast 189	a	—	160	—	170
quenched 353	a	—	347	—	350
Tempered 447	a	—	221	—	225
quenched 447	a	—	545	—	550
Tempered 447	a	—	292	—	290
quenched 447	a	—	718	—	700
BIERBAUM MICROCHARACTERS—					
Cu ₃ P	267	—	—	—	30
Cu ₃ Sn	750	—	—	—	200
SnO ₂	5,390	—	—	—	1,500
"Widia" tungsten carbide	—	—	—	—	1,450
WC + 3% cobalt	—	—	—	—	1,380
9% "	—	—	—	—	1,450
+ TiC and 13% binder	—	A 90	—	—	1,365
72 TaC + 20 W + 8 Ni ..	—	A 91	—	—	1,400
87 TaC + 13% binder ..	—	A 87	—	—	1,450
TaC	—	A 82	—	—	1,200
"Carbide"	—	—	—	1,050	950
"Firthite" sintered carbides ..	—	A 92, C 80	—	—	1,750
Silicon carbide	—	—	—	—	2,000
Boron carbide (moulded) ..	—	A 92-5	—	—	2,230
					2,000

will become slightly more populated in future as a result of research on hard synthetic materials. It might also be mentioned that pure silicon and pure boron prepared by Van Arkel's halide dissociation method, have Mohs hardness values lying between corundum and diamond¹⁷. As will be seen from Table VI, moulded boron carbide is the hardest artificial material now available, and it may be compared with some of the other compounds and constituents listed with it.

The increased use of micro-indenters will undoubtedly lead to the accumulation of data relating to the constituents recognised by metallographers, and it is not surprising that irons and steels have already yielded the results given in Table VII. Bearing metals also present opportunities for tests on individual constituents in the structure, and available values are given in Table VIII.

One of the great practical uses of micro-indentation methods concerns the study of treated surfaces and of

TABLE VII.
CONSTITUENTS OF IRONS AND STEELS.

	Brinell No.	Zeiss Scratch No. ¹⁹	Micro-Pyramid No.	Representative Diamond Hardness H _D .
FERRITE—				
Very pure iron	45	—	—	50
Electrolytic, low oxygen	66	—	—	65
" " high oxygen	69	—	—	70
Vacuum annealed, ordinary	70	—	—	75
Ordinary	80	5	—	85
" + 0-5 copper	100	—	—	100
" + 4-5 silicon	104	—	—	110
" + 1-5 silicon + 0-5 copper	135	—	—	140
Wrought iron, 0-23 phosphorus	120	—	—	125
" 0-47 "	148	—	—	150
In malleable cast-iron	—	—	182 ⁷	180
IRON CARBIDE—Fe ₃ C	650 ^a	30	820 ⁷	820
Chromium carbide, Cr ₄ C ₃	870 ^a	—	—	1,100
Molybdenum-tungsten-carbide	—	—	1,430 ¹⁰ 5,300 ¹¹	1,750
PEARLITE—				
Spheroidal (0-8 C)	125	—	—	130
Coarse—formed at 720° C.	170	—	—	175
Medium " 665° C.	296	13	—	300
Fine " 650° C.	319	—	—	330
Sorbite " 595° C.	377	—	—	390
In malleable cast-iron	—	—	390 ⁷	390
In cast-iron (0-8 P, H _{PS} 48)	—	—	395 ⁷	400
SORBITE (0-8 C)	350	—	—	425
TROOSTITE "	450	—	—	500
MARTENSITE "	780 (Carbide ball)	58	790/865	900
AUSTENITE (alloy steel)	200	—	—	220
Iron-graphite eutectic	—	—	—	130
PHOSPHIDE EUTECTIC	—	—	—	775

^aCornelius and Esser, Archiv. Eisenhütt., 1931, 8, 125.TABLE VIII.
HARDNESS OF CONSTITUENTS IN BEARING METALS.

Alloy and Test.	Ref.	Mass Hardness.	Primary Constituents.		Matrix.
			CuSn Needles.	Cuboids.	
A. TIN-BASE ALLOYS—					
Cu. Sb. Brinell test	a	—	—	90	20
4 10 Cone test	a	27	—	77	27
3 8 Scratch test	b	—	260	91-127	33
3 8 Micro-character	b	—	636	—	17
5 10 Pyramid	c	—	1,006	208	—
" " + 0-2 As Pyramid ..	d	30	215	62	23
" " + 5 Pb ..	e	31	159	84	25
" " + 0-2 As ..	f	32	290	68	26
" " + 0-2 As ..	g	35	182	85	27
" " + 0-2 Al ..	h	—	272	—	—
Representative H _D	—	29	200+	70	23
B. MEDIUM TIN ALLOYS—					
Pb. Sb.					
49 10 Cone test	a	23	—	77	11
" " Scratch test	b	—	—	101	20
29 9 Pyramid	d	23	—	77	22 and 17
" " + 0-2 As Pyramid ..	e	24	182	95	22 and 17
Representative H _D .. 30 Pb	—	23	200+	75	23 and 15
50 Pb ..	—	23	200+	75	15
C. LEAD-BASE ALLOYS—					
Sb. Pb.					
5 15 Cone test	a	26	—	—	23
" " Scratch test	b	—	—	101	36
10 15 Micro-character ..	c	—	—	246	9
11 13 Pyramid	d	25	—	90	20
" " + 0-2 As Pyramid ..	e	29	—	114	20
8 14 Scratch	f	—	200	280	—
Representative H _D	—	25	a phase 70	90	22
D. CADMIUM-BASE ALLOYS—					
Micro-character	b	—	—	NiCd ₇ 314	Cd-Ni 19 Cd-Ag 29
Representative H _D	—	—	—	100	Cd-Ni 25 Cd-Ag 35
E. COPPER-LEAD ALLOYS—					
Cu. Pb.					
60 40 Micro character ..	b	—	—	Cu 56	"Pb" 7-5
37 60 Pyramid	c	—	—	—	—

(a) Kennel and O'Neill, *J. Inst. Metals*, 1934, 55, 51(b) Swift, *Metals Technology*, Sept., 1938.

(c) Bierbaum, A.I.M.E., 1923.

(d) L.M.S. Research Department.

(e) Weaver, *J. Inst. Metals*, 1935, 1.

very thin strip or foil. In 1931 the author¹⁹ obtained results on electroplated specimens of normal coating thickness, and the more refined testing methods will now permit of further research in this direction. A collection of values obtained from the outer layers of treated metals is given in Table IX. The very thin layer produced by anodic coating is still associated with testing difficulties,

¹⁶H. O'Neill, *J. Inst. Fuel*, June, 1937.¹⁷*Metallic Science*, 1934, 12, 405.

TABLE IX.
HARDNESS OF TREATED SURFACES.

Treatment.	Major Diffusing Element.	Base Metal.	Maximum Diamond Hardness Rp.
Carburising and quenching	Carbon	Soft steel	900
Cyaniding and quenching	Carbon	Soft steel	930
Nitriding	Nitrogen	Alloy steel	1,000-1,300
		Alloy cast-iron	1,000
Cementation	Beryllium	O-12 C steel	268
		O-36 C steel	733
		O-9 C steel	1,506
		Grey cast-iron	1,561
	Boron 2-5%	Iron	240
	Boron sat.*	Steel	1,300-1,450
	Zirconium	Mild steel	250
"Ihrigising"	Silicon	Mild steel	304
			Cannot be sawn
"Follain" H.T. process	Aluminium	Mild steel	350
Cementation	"Gas"	Tantalum	700
"Sherardising"	Zinc	Mild steel	
"Floral" coating, 40μ thick	—	Hydronium	Outside 250 Inside 420
Chromium-plating (10 amp./sq. dm. 0.001 in. thick)	—	Hard steel	916

*Kontorovich and Lvovski, *Metallurgy*, 1939, 14, 89.

but reproducible results by impingement abrasion have been obtained by Schuh and Kern²⁰ and by Arlt²¹.

Perhaps the most important remaining hardness testing problem concerns specimens such as hardened steel or chilled cast-iron rolls, whose surfaces must not be blemished by the testing procedure. Here again the portable micro-indenters may be of some further service.

19 H. O'Neill, *Trans. Faraday Soc.*, 1931, 27, (2), 41.20 S. Schuh and Kern, *Ind. and Eng. Chem. Anal. Ed.*, 1931, 3, 72.

21 H. G. Arlt, A.S.T.M. Preprint, 1940.

Metallurgical Factors Governing the Selection of Light Alloys for Internal Combustion Engines

A WIDE range of aluminium alloys is available for various components of the modern internal combustion engine, the compositions and properties of which are adequate to meet the economic and technical requirements of production and operation. Various suitable alloy groups and compositions are examined in a recent issue of *Aluminium Technique*,* which deals with types of castings; aluminium-zinc alloy for stressed parts; applications of aluminium-copper alloys; the importance of pressure tightness in castings; requirements of piston alloys; copper-bearing piston alloys; technical and economic value of the aluminium-silicon alloys; silicon-bearing piston alloys; silicon alloy for cylinder blocks and heads; aluminium-magnesium alloys in aircraft and marine engines; economic significance of casting alloys; wrought forms replaced by castings; respective merits of the three casting systems; use of forged components; composition considered as a controlling factor; and the influence of current trends on factors controlling selection of alloys.

Under the last heading it is stated that current trends in design exert a profound effect on metallurgical factors governing the selection of light metals for internal combustion engines. Just as the light-alloy cylinder head was adopted in the interest of increased thermal efficiency, so higher operating speeds and increased power/weight ratio provide further opportunities for the advantageous use of strong aluminium-base alloys, but, at the same time threaten to make still heavier demands on the materials employed. More stringent requirements are being met by the development of new alloys capable of withstanding increased thermal stresses and by the evolution of heat-treatable alloys, the properties of which may be improved and controlled to meet specific and exacting conditions encountered not only in the service life of a component, but also in its economical production.

On one page of this issue is listed the uses of aluminium and its alloys in modern aircraft. The lists are given under three main headings: the aircraft frame; engine components; and accessories. The descriptions given refer to accepted forms, but may variations are possible according to the type of machine and production method employed.

No. 12, published by Aluminium Union Limited, The Adelphi, London.

Influence of the Rate of Cooling on the Transformations and Properties of Chromium Steels

MUCH work has been published on the quenching of chromium steels, and an attempt has been made by Rose and Fischer* to verify and enlarge, by improved methods of experimenting, the results found in earlier investigations. During the present investigations the annealing took place, in an atmosphere consisting of a mixture of hydrogen and coke-oven gas, for two to five minutes at 1000° C., and the test pieces were quenched, with different rates of cooling, from 2° C. per second up to 300° C., according to the chromium content of the steel.

Twenty-two different steels were investigated, which, according to the chromium content, could be divided in six groups with about 0.3, 0.7, 1.0, 1.3, 2.0 and 3.7 per cent. chromium. In each group three or four steels with different carbon contents, between 0.3 and 1.7 per cent. carbon, could be distinguished.

Undercooling diagrams summarise the results obtained, from which it is seen that three stages of undercooling took place when more than 0.3 per cent. chromium was present: the pearlite stage, the intermediate stage, and the martensite stage. Each stage was characterised by its structure and hardenability, details of which are given in the original work. The critical cooling rate was lowered considerably by small additions of chromium; with 1.0 per cent. chromium and eutectoid carbon content it reached about 30° C. per second, i.e., about a seventh of the critical cooling rate of unalloyed steels. The transformation in the intermediate stage was limited to steels of certain chromium and carbon contents.

The second part of the report deals with the nature of the intermediate stage. The pearlite and intermediate transformation had two distinctly separated maxima of the rate of austenitic precipitation at 680° and 480° C. This has been determined by isothermal magnetic measurements. It would further be revealed by measuring the Curie-points of test pieces, partly transformed in the pearlite and partly in the intermediate stage, in the intermediate stage a carbide of considerably less chromium content is developed than in the pearlite stage. The same carbides, however, were obtained if quenched martensitic steels are tempered for 20 minutes to temperatures of the intermediate or pearlite stage. From a microscopic examination of the structure a further idea could be obtained of the course of the transformation in the intermediate stage: it begins very quickly on certain points, where a needle-like structure results.

Technological investigations of the mechanical properties of steels transformed in the intermediate stage showed, for low carbon steels (0.30 to 0.35 per cent. C), a considerable improvement against those which were annealed in the usual way; they approach nearly the values of tempered steels.

Honour for Professor Joffe

FOR his outstanding work in physics, Professor A. F. Joffe has been awarded the Order of Lenin, the highest honour in the Soviet Union. The award was made on the occasion of Professor Joffe's sixtieth birthday and the thirty-fifth anniversary of his scientific career.

Professor Joffe's study of the mechanical and electrical properties of crystals gained him a world-wide reputation. His works on elementary photo-electric effect and the magnetic field of projectiles are of great scientific importance. The last few years he has devoted to the study of semi-conductors. He was responsible for the formation of the Physico-Technical Institute in Leningrad in 1918, the first of an entire system of physico-technical and physico-chemical institutes in the Soviet Union—in Kharkov, Dnepropetrovsk, Sverdlovsk, Tomsk, etc.

*Ad. Rose and Wilhelm Fischer, *Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung in Düsseldorf* vol. XXI Nr. 8.

Magnesium Alloy Pressure Die Casting with Special Reference to "Elektron" Alloys

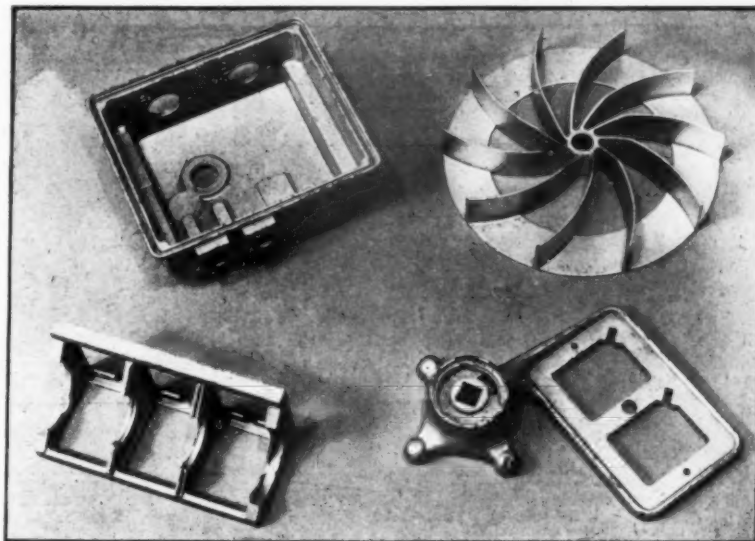
Saving weight without sacrifice of stiffness or increasing the stiffness of structures without exceeding a given weight are important advantages resulting from the use of magnesium alloys. "Elektron" magnesium alloys have been successfully applied for a variety of purposes for many years; in recent times, however, great progress has been made in the utilisation of "Elektron" pressure die castings, and in this article attention is directed to their production.

THE rapidly increasing use of light metals is undoubtedly due to the metallurgical and engineering development which has taken place in direct response to pressing demands for light-weight materials possessing qualities favourable for constructional purposes. The aircraft and automobile industries, for instance, largely owe their remarkable progress to these developments. But, in addition to the industries which are included in transport engineering, certain of the chemical, food and electrical industries introduced problems which have been successfully overcome by the use of light metals, and, to-day, there are few industries which do not include light metal parts in their manufactures. In some instances the use of these materials has become essential, while in others their special characteristics place them in a favourable position in comparison with the heavier metals and alloys.

Of the light metals possessing qualities favourable for constructional purposes, magnesium alloys have rapidly occupied a conspicuous place, and about 80% of the alloys used are "Elektron" alloys produced by Magnesium Elektron Limited. To-day, they are being employed for purposes which would have seemed extremely unlikely only a few years ago, and the demand is growing. Active research has kept pace with these increasing demands of the engineering industry, and it is being rewarded constantly by increasing knowledge of favourable alloying elements and by other factors which have advanced the quality of the finished article.

The main advantages of "Elektron" magnesium alloys are their low specific gravity and high strength/weight ratio; good machining qualities, which exceed other metals; high resistance to fatigue; good heat conductivity; and other favourable properties dependent upon the form in which they are used. The specific gravity of "Elektron" magnesium alloys ranges from 1.80 to 1.83, which is approximately $\frac{2}{3}$ the specific gravity of aluminium, and about $\frac{1}{4}$ of that of steel. Tensile strengths up to 22 tons per sq. inch are obtainable after heat treatment, with a fatigue resistance range of 8.9 to 9.0 ton per sq. inch on 20 million reversals of plain bar. These qualities, combined with ease of fabrication and freedom from pinholing in castings, and ease of welding and forging, have, in many cases, led to the substitution of "Elektron" magnesium alloys for other metals and alloys.

Magnesium alloys were originally introduced as "Elektron" castings, and although they are widely used as sheet, strip, extruded sections, and as forgings, it is in their first form in which they are probably more familiar in this country. As sand castings especially, these alloys are well known, and their value in the present emergency is greatly appreciated; they give excellent results in the most complicated formations and have a finish and defini-



An electrical switch case, an impeller and other pressure die castings in "Elektron" alloys.

tion at least comparable with any other metals or alloys. But in recent years considerable progress has been made in the application of magnesium alloy pressure die castings, and it seems profitable to discuss this aspect of casting production.

Characteristics of Pressure Die Casting

The outstanding characteristics of the pressure die casting process are the high degree of accuracy of the castings and the relatively fast rate at which they are produced. The smooth surfaces produced ensure a very high degree of accuracy in dimensions which leads to considerable saving in fabrication costs; dimensions and tolerances of pressure die castings are defined in thousandths of an inch. This accuracy makes possible the reduction, and frequently the total elimination, of machining operations; it also results in uniformity in the castings produced. When machining is essential, the machinability of "Elektron" magnesium alloys is so easy that very small machining allowances are needed, from 10 to 20 thousandths being ample in most cases, enabling savings to be effected in material and machining costs.

"Elektron" magnesium alloy pressure die castings combine the accuracy, uniformity and superior surface finish of die castings in general and the lightness characteristic of these alloys, and their low viscosity in the fluid state permit the production of thin-walled and complicated castings. They have a higher melting point than many other white metals that are pressure die cast, and die castings made from them possess stability of form and dimensions under normal conditions of service. Another useful advantage is the good bearing quality of "Elektron" alloys, which permits the direct contact of moving parts, providing the surfaces are adequately greased.

Mechanical properties can be greatly improved by heat treatment, although this is not usually necessary, as magnesium pressure die castings have not so far been used for stressed members, and the mechanical properties in the "as cast" condition are normally adequate.

Production Technique

The pressure die casting of magnesium alloy is comparatively new in this country, and considerable development work has still to be carried out. It has been suggested that certain fundamental defects are encountered in pressure die casting these alloys, but these are more likely to be due to unsuitable technique in production, because the pressure die casting of "Elektron" alloys has been carried out successfully by Messrs. Birmingham Aluminium Casting (1903) Co., Ltd., during the past three or four years, and the applications are of such a character that considerable development has and will result.

The special peculiarities of magnesium alloys naturally call for a separate technique in their fabrication. As far as pressure die castings are concerned, one of the difficulties is heat conductivity. Aluminium alloys conduct considerable heat to the die, but in the case of magnesium alloys it is necessary to preheat from some external source in order that a uniform working temperature may be maintained. As a general rule dies for this alloy are lighter in section in order to reduce heat losses in the die by conduction. One other important point in favour of "Elektron" alloy is the fact that there is no chemical effect on the steel dies, and as a result of this the output from a single die is greatly increased. (It is claimed that under normal conditions 50% greater output is obtained from a die when pressure die casting "Elektron" magnesium alloys than when casting aluminium alloys.)

Die wear is, of course, encountered just as when pressure casting any metal or alloy, and it is this wear which places a limit on the number of castings which can be produced in a particular die, although when close limits are not specified and other conditions are favourable, the output of a die may be as high as 500,000 castings. Usually the output ranges between 40,000 and 100,000 castings, according to the complexity and size of the design. The size of casting which can be produced by the pressure process is determined by the limitations of existing casting machines, usually, however, with the increase in size of castings the quality of the product is lower and the gravity process may prove more economical.

"Elektron" magnesium alloys may often be pressure cast in dies similar to those used for aluminium alloys, but when they are specially prepared for "Elektron" the sectional thickness can be reduced and a slightly increased taper should be allowed to facilitate the ejection of each casting. As is usual in the die casting of other metals and their alloys, sudden change in sections should be avoided and careful attention should be given to radii at the junctions of the sections. Chromium tungsten steel is recommended for the parts of the die in contact with the molten metal, and it should be hardened to 38/42 Rockwell. When cores and loose parts are inserted, these must be very accurately fitted and given liberal draft. In some cases the cores must be made to collapse in the direction of a key part to ensure easy removal from the casting. The dies should be well vented at the high points to ensure that no air is trapped, and they should be coated with a mixture of boric acid, french chalk and water.

Although the melting point of magnesium alloys is approximately 625° C. the temperature at which they are pressure die cast is generally much higher. This practice is different from other alloys, which are usually cast at or near the lowest temperature at which they will completely fill the die, in order that the resulting casting will be sound. With magnesium base alloys, however, no appreciable gas absorption has been observed when superheated to a temperature of 850° C., and rapid cooling of the metal

in the die results in marked grain refinement, which improves its mechanical properties.

The success of the pressure die casting process is largely dependent on the condition of the metal when forced into the die, and careful consideration must be given to the melting procedure. The alloys may be melted in furnaces heated by coke, oil-fuel, gas or electric resistance furnaces may be used, but the form of heat applied must maintain the metal at a uniform temperature for die casting purposes, and the use of gas is usually recommended. Magnesium oxidises readily in contact with the atmosphere, and the melting furnace and casting machine must be designed so as to expose as little of the molten metal as possible to the air. Special machines have been developed with this in view. In these the metal is melted in furnaces which are integral with the machine, and the metal surface is protected from the outside atmosphere by means of a flux cover. The flux used is the same as that employed when refining the metal, but the specific gravity of the flux is such that when the molten metal is clear of impurities the flux forms a cover on the surface of the melt and protects the metal from the outside atmosphere. The metal passes from this melting pot into a holding pot with a closed top; any air remaining between the metal surface and the top of this pot very quickly becomes exhausted, although in most cases an SO₂ atmosphere is supplied to neutralise the effect of the air. The metal is lead from the holding pot into a specially designed pressure chamber and pressed into the die by means of a piston.

The fluxes used for refining and protection of magnesium metals generally have magnesium chloride as their base, and besides the Melrasals used by "Elektron" fabricators, many proprietary fluxes are offered which are combinations of MgCl₂ and other salts. These mixtures must not only remove existing impurities, but the flux and impurities must separate readily from the molten metal. The amount of flux normally used is between 3-5% of the weight of the melt. This can vary considerably according to the type of melt being refined. In cases where impure metal is being used, more flux is naturally required.

The sand and gravity die casting "Elektron" alloys are also generally suitable for pressure die casting, and particulars of the "Elektron" series in widest use are given in Table I, together with the D.T.D. specification to which the alloy corresponds:—

TABLE I.

Designation.	Composition %.								Specification.	
	Al %	Zn %	Mn %	Pb %	Cu %	Si %	Sb %	Fe %	As Cast.	Heat- treated.
"Elektron" AZ 91.	9-11	3-5	0-5	0-4	0-4	0-4	—	0-3	DTD 136A	DTD 281 or 285
"Elektron" A 8.	8-5	3-5	0-5	0-4	0-4	0-4	0-4	0-1	DTD 30A	DTD 289

TABLE II.
MECHANICAL PROPERTIES.

	0-1% Proof Stress, t.s.l.	Maximum Stress, t.s.l.	Elongation.
"Elektron" A 8 (H.T.) to DTD 289	4-5-5-5	14-16	9-11
"Elektron" AZ 91 (H.T.) to DTD 281	3-6	14-16	7-9
"Elektron" AZ 91 (fully H.T.) to DTD 285.	7-9	15-17	3

Surface Protection

Early experience with magnesium and magnesium alloys gave rise to the impression that they were particularly susceptible to corrosion, but research into the mechanism of corrosion has shown that accurate control during the refining of the metal renders the alloys practically immune from attack in normal atmospheric conditions. Little effect has been noticed on samples exposed for ten years in the open apart from discoloration. There was no pitting action to which many aluminium alloys exposed under similar conditions are subject. "Elektron" alloys are not, however, generally suitable for parts in frequent or constant contact with water, such as water pump bodies, etc.,

while the action of sea water calls for very special precautions. On the other hand, "Elektron" alloys are corrosion resistant in alkaline solutions. While these alloys can be polished, the bright polished surfaces soon tarnish on exposure by the formation of an oxide film which is also protective in nature. Therefore, they should not be used for components that are to remain brightly polished, unless the surface can be greased, or otherwise protected. Few constructional materials are completely immune from attack by sea water, and some form of surface protection is almost always necessary.

As far as "Elektron" pressure die castings are concerned the usual method of protection is treatment in the acid chromate bath (British Patent No. 287450, owned by Magnesium Elektron Limited) followed by lacquering or painting with a suitable approved material to D.T.D. 63A, DTD 260A, DTD 308, and DTD 314. A licence must be obtained from Magnesium Elektron Limited to use this bath.

In cases where close tolerances are necessary, great care should be taken when dipping the casting in the acid chromate bath, as dimensional losses occur. The casting should only be dipped for a matter of a few minutes and be kept moving all the time. Full particulars of this and other baths can be found in the "Elektron" handbook.

The surface of the metal turns a bronze colour after treatment in this bath, and as well as affording protection to the metal surface the chromate film gives an excellent base for subsequent finishes.

Applications

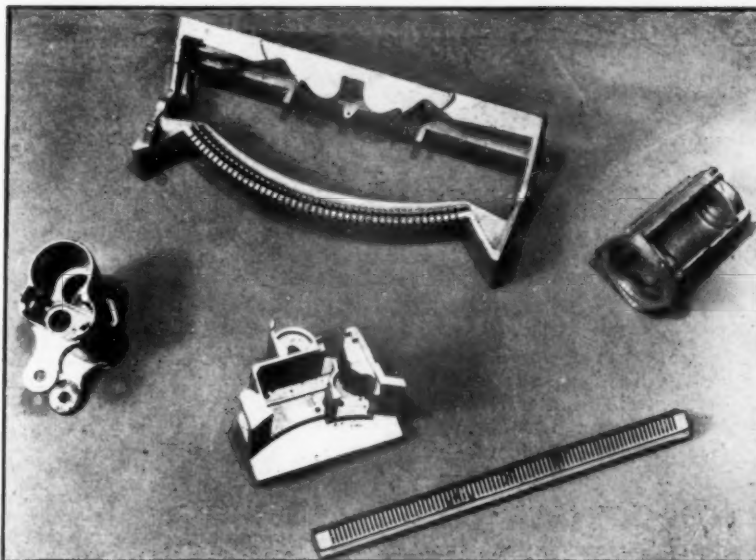
"Elektron" magnesium alloys have found wide application in this country either in the form of sheet or in the forged or cast conditions. It is not surprising that to-day practically every aeroplane and aero engine in production incorporate these alloys. Until now, however, the application of pressure casting processes has been somewhat retarded, as orders for large quantities are required to warrant the manufacture of special tools and, furthermore, little use has been made of "Elektron" in this form for constructional parts although investigation of applications of this type would undoubtedly lead to the use of increased quantities of the pressure die cast metal for aircraft purposes.

In other industries, including the motor industry, the optical industry, office machine industry, etc., large quantities of "Elektron" pressure die castings have been manufactured and supplied for a variety of purposes, and have proved entirely satisfactory. Some of the most popular applications are shown in the accompanying illustrations, but many other applications show a growing appreciation of these alloys.

"Elektron" pressure die castings are suitable for moving parts in automatic machinery for portable tools, laboratory apparatus, wireless apparatus, gauges, binoculars and camera bodies, typewriters, cash registers and calculating machines, and some use has been made of them in the manufacture of surgical apparatus such as X-ray machines.

One of the main elements in the wider application of "Elektron" pressure die castings is the small maximum size of casting obtainable, owing to the capacity of existing machines. One of the main possibilities of development rests with the manufacturers of pressure die casting machines, who should, with the assistance of the foundries, be able to develop a more efficient machine, capable of producing larger and more complicated castings.

An unfortunate limitation at present in the use of



A binocular casing, a typewriter frame and lever bar, as well as other pressure die castings in "Elektron" alloys.

magnesium alloys is the lack of knowledge as far as many designers are concerned. This is, of course, partly due to the fact that the whole technique of handling these alloys was, and still is to an extent, in a state of development, but there is an abundance of informative literature available on all branches of the fabrication of "Elektron" alloys, and any engineer is able to obtain these from the industry, free of charge.

The progressive future of "Elektron" alloys is assured, but full advance of applications is mainly in the charge of engineers and designers to whom one must look for discerning usage of those good qualities and advantages which are being achieved by the producers of the metals and the experienced fabricating firms.

Sodium Potentials

The experimental conditions necessary in order to classify metals by means of their solution potentials are described in detail by Goldowski.* The potential is the result of the internal heterogeneity of the metal and the external heterogeneity of the surface coating. The nature of this surface depends on the surrounding medium, and regularities in relative potential measurements are due to this coating; it is necessary to distinguish between the potential of the metal and of the metal with the surface layer. Variations in potential are also due to different methods of measurement. The coloriscope method is recommended under certain conditions for the determination of differences in potential. With similar light alloys distinct differences in the curves, $V = f(t)$, were obtained; there was no similarity among steels. It was not possible to relate the solution potential curve and the tendency to corrosion. The potential corresponds to a limited surface and never reproduces the conditions exactly; in many cases the results were not as expected from potential measurements. Accidental rupture of the surface layer contact with corrosion products, pH, aeration and agitation can completely change the behaviour of a metal with respect to an electrolyte. 241 references are given.

Lead-Sodium Alloy as a Drying Agent

The use of the lead-sodium alloy NaPb in place of metallic sodium for drying inflammable liquids is recommended by Soroos† as an agent less hazardous to handle. It can also be more easily brought to a fine state of subdivision. The author describes the preparation of the alloy on a small scale.

*Nathalie Goldowski, *Publ. sic. tech. ministère air*, 1939, **158**, 102 p., C. Abs., 1940, **44**, 4,966.

†Harold Soroos, *Ind. and Eng. Chem. (Anal. Edn.)*, 1939, **11**, (12) 657-658.

Some Hot-Rolling Tests

Determination of the Forward Slip in Hot-Rolling Tests

THE forward slip of material rolled against the rolls is considered one of the most important figures of the rolling process; it enables conclusions to be drawn regarding the position of the yield point, the extent of the friction and of the angle of friction. Generally, the determination of forward slip is effected by measuring impressions left on the material by marks on the rolls. This is not difficult when cold-rolling, but when hot-rolling measurement is made on the cooled down surface an allowance must be made for contraction. The latter can be calculated if the contraction figure and the temperature of the material during rolling is known. Few simple mathematical equations can be developed showing the relation between these figures—for example, it is

$$\times = \frac{a_1 \times (1 + \beta t) - a_0}{a_0}$$

where \times = real forward slip,

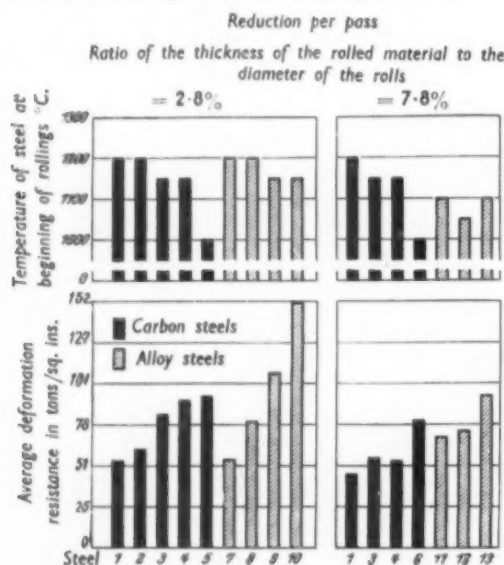
β = contraction figure,

t = rolling temperature in °C.,

a_1 = distance between marks on cooled-down surface,

a_0 = distance between marks on the rolls.

Forward slip taken from reports of four investigations on 15 different steels have been studied* and checked by means of this equation, and it is shown that, without consideration of the contraction, conclusions regarding the extent of the forward slip, the influence of the rolling temperature on the forward slip and the rolling friction have been drawn which do not correspond with the facts. This is especially true of investigations on high-alloyed steels rolled at temperatures exceeding 1,000° C.



Hot-rolling tests on a carbon and three alloy steels were carried out in order to compare results with those of earlier investigations. The rolling tests were carried out at a range of 700° to 1,200° C. on a carbon steel containing 0.88% carbon, a chrome-molybdenum steel, a nickel steel, and a nickel-chrome steel. The rolling pressure, the power consumption and the dimensions of the material before and after rolling were measured. It was found that the influence of the reduction per pass and of the rolling

temperature on rolling pressure, deformation resistance and rolling output was as expected; that the forward slip and the increase in width was dependent to a large extent on the reduction per pass, and to a much less extent to the rolling temperature. The steel analysis had an important influence only when rolling a high-alloy stainless steel for cutlery; a considerable increase of the rolling pressure, of the average deformation resistance and of the power consumption took place; forward slip and increase of width, however, were practically unaffected.

Thirteen steels investigated were first compared with regard to their behaviour when rolled at the same rolling temperatures. The deformation resistance of carbon steels decreases with increasing contents of carbon, but not to a very large extent. Alloyed steels differ from carbon steels only if they are of austenitic structure. In these cases a considerable increase of the deformation resistance takes place. In practice, however, the deformation resistance changes with the rolling temperatures is of greater importance, since temperatures must be varied according to their effect on the structure and mechanical properties of the steels. As is well known, steels with high-deformation resistance must be rolled at comparatively low temperatures, thus the difference in rolling soft steels with low-deformation resistance becomes still greater. The result of this comparison is clearly indicated in the accompanying illustration.

ANALYSIS OF CARBON AND ALLOY STEELS.

No.	C.	Si.	Mn.	P.	S.	Cu.	Ni.	Cr.	—
1	0.08	0.05	0.06	0.005	0.010	—	—	—	—
2	0.11	0.22	0.50	0.020	0.018	—	—	—	—
3	0.28	0.22	0.50	0.009	0.011	—	—	0.24	—
4	0.43	0.28	0.68	0.011	0.017	—	—	0.03	—
5	0.88	0.18	0.63	0.014	0.016	—	—	—	—
6	0.88	0.32	0.44	0.012	0.009	0.11	—	—	—
7	0.06	1.19	0.29	0.010	0.002	—	0.14	22.50	2.23 Al
8	0.11	0.63	0.64	0.015	0.026	—	9.10	18.40	—
9	0.14	1.90	0.69	0.015	0.010	—	20.50	25.00	—
10	0.47	1.98	0.85	0.015	0.010	—	13.70	15.40	1.95 W
11	0.13	0.26	0.51	0.021	0.014	0.13	3.74	—	—
12	0.37	0.28	0.00	0.015	0.014	0.15	—	1.05	0.17 Mo
13	0.41	0.33	0.38	0.014	0.011	0.08	0.20	13.00	—

Zinc Alloy Dies for Aircraft Stampings

DEALING with the production of aircraft stampings in the Douglas plant, Chase* devotes considerable attention to parts which are quite large and necessitate deep drawing. A considerable proportion of the dies for this purpose are cast from soft metals and very close to the required size. A primary objective is to minimise machining of the die, as only thus can its cost be made low enough to warrant the investment. Casting is simplified by selecting an alloy of fairly low melting point and one which, when it has served its purpose, can be remelted for further use.

The alloy chiefly used in the Douglas plant is known as "Kirk-site A," but it is quite similar to the Zamak alloys, or to the Mazak alloys in this country, which are used extensively for die castings in other industries, and also for many stamping dies in other aircraft plants. Dies from these alloys are much stronger and harder than antimonial lead, but the latter is still used for the "punch" or the upper half of the die, largely because—since the melting point of lead is much lower than that of these zinc alloys—the punch die can be cast by using the zinc alloy lower half as a mould. In other cases, both halves of the die are made in the zinc alloy.

These zinc alloy dies are not used in conventional stamping presses, but in rope drop hammers. Drawing is rarely done in a single blow of the punch but in several blows, and, in some instances, a progressive die having two or more stages is required. In general, however, only a single cavity die is needed, but the operator controls the number and force of the blows struck to yield a piece of the required shape, that is, one which, at the final blow, fits accurately both the punch and the die.

* Werner Lueg and Anton Pomp, Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf. Vol. XXI, No. 10.

* Herbert Chase, *Metals and Alloys*, Vol. 12, No. 4, 1940, pp. 436-41.

Electrical Detection of Flaws in Metallic Tubing

Modifications of the electrical method of flaw detection are discussed; they have been found suitable for testing any type of metallic tubing, including plain carbon and alloy steels, stainless steel of the non-magnetic or austenitic type, copper, brass, aluminium alloy, nickel and its alloys, in fact, any type of metallic tubing.

METAL tubing, both ferrous and non-ferrous, is extensively used as an engineering material on account of its peculiar combination of properties, including maximum strength and rigidity with minimum weight, as well as the capacity to conduct fluids under pressure. There are three principal methods of producing tubing, including: (1) Forming from a flat strip and welding the seam by mechanical pressure, by acetylene or electric arc, or by electrical resistance; (2) Piercing a solid billet, followed by rolling; (3) Extrusion of non-ferrous metals. After any of these methods, size and wall thickness may be reduced by cold drawing. Whatever method is used the product is subject to mechanical defects or flaws, and as engineering and fabricating requirements become more exacting, the importance of freedom from such defects and imperfections increases. It is of interest, therefore, to note a new method for the non-destructive testing of welded or seamless tubes, bars, and other articles of ferrous and non-ferrous metals, generally in cylindrical form described by H. C. Knerr,* a method claimed to be applicable to non-magnetic as well as to magnetic material.

In the art of non-destructive testing for metallic materials, magnetic testing, whereby the measurement of magnetic characteristics yield desired information as to the mechanical properties of steel parts and lead to the location of flaws and discontinuities, has had considerable practical application. This magnetic method, however, has certain serious limitations, since it is not applicable to non-magnetic materials, and even when applied to steel or other magnetic material, harmless variations in mechanical properties often create larger variations in magnetic indications than are caused by serious defects. The new method of testing has been developed as a non-destructive test for metallic materials, especially tubing, in order to test non-magnetic as well as magnetic materials and to detect mechanical flaws with a high degree of sensitivity, and makes use of electrical instead of magnetic methods for testing.

The advantages of electric current over magnetic flux are pronounced. A mechanical discontinuity such as an open seam opposes over its area practically infinite resistance to the transverse flow of electric current, provided that the voltage is not sufficient to cause an arc. If the surfaces of the seam are in contact, as may occur, if imperfectly welded surfaces have been squeezed together in drawing through a die, then some flow of electric current will occur, but such opposed surfaces even if clean, present an electrical resistance much greater than an equal path of solid metal. The method of testing is therefore to cause a flow of electrical current under controlled conditions transversely to the direction of a possible flaw, and to measure the effect of the flaw on such current, and such a method may be carried out in several modifications.

One method is to pass a tube through a set of energising coils carrying alternating current, thereby inducing circumferential currents in the tube walls. If two metallic tubes, identical except that one contains a flaw, are each surrounded by a similar electrical winding or test coil, then the reaction of the coils upon the alternating current flowing in each of them will differ as the result of the flaw. A substantial flaw extending longitudinally will interpose resistance to the passage of this induced alternating current, which will therefore be less than if the

flaw were not present, or the phase relation may be changed. This difference can be measured externally electrically, and highly sensitive and accurate electrical measurements are possible, whereby minute variations are amplified and recorded by the aid of electron equipment.

Defects in tubing may be broadly divided into three classes: (1) open seams, (2) seams or longitudinal flaws extending partially through the tube wall, but of considerable length, (3) short flaws, and openings of very short length, sometimes referred to as pinholes. A long defect extending fully or partially through the wall of a tube of moderate diameter will have a sufficiently pronounced effect upon the circumferential resistance to be readily detected by the use of detector coils extending completely around the tube. The short flaw or pinhole presents a somewhat different problem. Here the circumferential current is in effect merely deflected around the flaw, and the effect upon the circumferential resistance of an appreciable length of the tube is extremely small, so that a different method of detection has to be developed.

A method of detection known as the tangent coil method is used. This method is based upon the principle that while the effect of a small flaw upon the total circumferential current is small, there is an area closely adjacent to the flaw from which the current is almost completely deflected by the flaw, so that in this small area the change in current is great. By placing a conductor of short length in close inductive relation to the area immediately adjacent to the flaw, a relatively large change in inductive effect can be obtained in this small conductor. A coil or set of coils is therefore provided, shaped something like the letter "D." That portion of the D coil which is closely adjacent and tangent to the tube wall is short, its length being comparable with the length of the short flaw to be detected with maximum sensitivity. The portions of the D coil which extend radially from the tube are in non-inductive relation thereto, and are fairly long, while the connecting or outer segment of the D is far enough away from the tube to have relatively little inductive effect. As it is easier to detect differences in inductive effect upon two similar coils than to detect variation in one coil alone, a series of coils may surround the tube, such coils being arranged in opposite pairs so that a flaw under one coil will not have an effect upon the other. If no flaws are under either, the inductive effect of the two coils will be in balance and no indication will be produced. Presence of a small flaw under one will destroy the balance and consequently give an indication.

The tangent coil method avoids certain difficulties which are encountered with circumferential coils. Changes in temperature in a tube change its resistance, but as the tangent coils are sensitive only to local variations, a change in the entire circumferential resistance of a tube will affect both coils equally and therefore produce no indication. In a tube of large diameter, the relative effect upon the total circumferential resistance produced by a flaw is small, but since the tangent coils measure differences existing in two short circumferential arcs of a tube, the total diameter of a tube is unimportant. Tangent coils, however, being adapted for high sensitivity to short flaws, are less sensitive to long flaws, and under certain conditions a combination of the two coil systems, circumferential and tangential, may be necessary.

Another modification of the electrical principle of

* *Metals and Alloys*, 1940, Vol. 12, No. 4, pp. 464-469.

testing embodies the use of contactors. Circumferential current is caused to flow in the tube which is then passed longitudinally under two or more circumferentially spaced contact points, differences in potential between such points being picked up and amplified by the detecting apparatus. A flaw occurring between any pair of points can be readily detected. Wear of contactors and electrothermic effects, however, cause certain difficulties, as well as does the maintaining of continuous perfect contact.

The electrical method of flaw detection in its various modifications has undergone considerable development and has been found suitable for testing any type of metallic tubing, including plain carbon and alloy steels, stainless steel of the non-magnetic or austenitic type, brass, copper, aluminium alloy, nickel and its alloys, etc. Typical applications include tubes for aircraft, axles, boilers, Diesel engines, electronic tubes, radiators, and refrigerators.

A New Die Steel

By L. Sanderson

The range of die steels to meet modern needs is considerable, but there will always be room for a new steel which is economical in service and the die steel discussed in this article is claimed to effect a 40% saving in die cost on short run dies, further, that it gives excellent results in service.

THERE is already a fairly wide range of die steels in existence for different purposes, but comparatively little attention appears to have been paid in the past to die steels for dies used in the production of cold-formed or stamped parts where only short runs are required. This makes the development of a new die steel specially suitable for this type of die of considerable importance. Dies for short runs on the type of materials mentioned have to be accurate, withstand any tendency to fracture, and give good wearing properties, while they must be of reasonable cost and simple in heat-treatment, so that die cost per stamping can be lessened.

Hitherto, the user of die steels for short run work had to choose between the manganese chromium tungsten oil-hardening die steels and the air-hardening high-carbon high-chromium die steels. The oil-hardening steels are reasonable in price, but they cannot be said to be wholly without distortion, though this distortion may be reduced to a minimum. The high-carbon, high-chromium steels have better non-shrinking and non-distorting properties, and admirable wear resistance, but their first cost is extremely high for short runs, while they are not among the easiest of steels to machine.

Obviously, a steel for short die runs is required that will unite the advantages of both types, while omitting their disadvantages. An ideal specification of properties would include high resistance to wear, minimisation of warping after quenching, and the ability to take and hold a high degree of hardness when tempered, together with low first cost and easy machining. Experiment along these lines has finally led to the development of a steel containing chromium, molybdenum, and vanadium. The vanadium is added to provide a wide range of heat-treatment; and to prevent excessive grain growth; the molybdenum is added to give high hardness, and to improve the hardness after tempering. The effect of molybdenum on the hardness of 1% carbon, 5% chromium steel after tempering is shown in Tables I and II. The analyses of the three steels in question were as follows:—

	Carbon, %	Chromium, %	Vanadium, %	Molybdenum, %
Steel 1	1.03	4.89	—	—
" 2	1.00	4.94	0.20	0.48
" 3	0.97	5.05	0.18	1.07

TABLE I.

Air-hardening Temperature Deg. C.	Rockwell C Hardness.		
	Steel 1.	Steel 2.	Steel 3.
925	39	46	64.5
955	49	51	65
980	54	64	65
1010	54	64	63

Table II shows the relative influence of different tempering temperatures on the steels after air cooling 980°C.

These tables reveal some important points in regard to

TABLE II.

Tempering Temperature, Deg. C.	Rockwell C Hardness.		
	Steel 1.	Steel 2.	Steel 3.
As quenched	54	64	65
150	50	62	62
205	50	60	61
260	50	60	60
480	49	56	58
510	49	51	59
540	—	—	58

the hardness characteristics of the 5% chromium, 1% molybdenum steel. In the first place, complete hardening in air is secured at a relatively low temperature (925°C.) in smaller sections, e.g., up to 1 inch thick. Higher temperatures, up to 980°C. are necessary for larger sections. Secondly, there is a considerable secondary hardening effect at tempering temperatures between 510 and 540°C., when the steel is quenched at 955° or 980°C. This secondary hardness matters for the reason that an improvement in strength goes with it. Lastly, the steel keeps its hardness to a noteworthy extent at low tempering temperatures.

Facts drawn from experiments conducted both in the research laboratory and in production show that distortion after hardening is negligible. The low tempering temperature is feasible because of the minimum stresses occasioned by air hardening. Table III shows the results of two tests on rings, the data given being averaged from two sets of tests.

TABLE III.

State of Ring.	Dimensions in Inches. Test Ring 1.				
In advance of heat-treatment	2.8988	5.0004	1.0012	0.4996	
Change after hardening	+0.0005	+0.0033	+0.0006	+0.0011	
Change after tempering at 150° C.	-0.0009	+0.0016	+0.0002	+0.0013	
Change after tempering at 205° C.	-0.0015	+0.0010	+	Nil	
Test Ring 2.					
In advance of heat-treatment	2.8981	5.0006	1.0010	0.4995	
Change after hardening	+0.0011	+0.0017	+0.0007	+0.0001	
Change after tempering at 150° C.	-0.0005	-0.0004	+0.0004	+0.0002	
Change after tempering at 205° C.	+0.0005	-0.0018	+0.0002	+	Nil

A typical heat-treatment for dies made from this new steel is as follows: pack harden and air quench from 980°C., afterwards tempering at 205°C. for three hours. This should give a final Rockwell hardness of 61C. The first cost of the new steel is moderate as compared with high-carbon high-chromium die steel. Machining costs are also highly economical. In certain instances grinding after hardening has not been necessary because the dies heat to their original size after heat-treatment.

In general, it is claimed for the new steel that it enables a 40% saving in die cost on short run dies to be made. Furthermore, it gives excellent results in service, and although originally designed for dies, it has since been applied to a wide range of parts among which may be mentioned cams, clutch parts, bearing ways on lathes and grinders, wearing strips or inserts, hot work dies, rolled thread dies, plugs and gauges.

Alkaline Cleansers for Cleaning Metal Components

By P. Mabb

Metal articles have to be degreased for various purposes, and the introduction of many new alloys and metals has caused wider search for suitable alkalis to effect this operation; the mechanism of alkali cleaning has also been studied with a view to rendering the operation rapid and effective. Suitable cleansers are discussed, various operations reviewed, and brief reference made to cleaning equipment.

METAL articles have to be degreased for various purposes—viz., for convenience of handling or for subsequent machining operations, as a preparation for electroplate or enamel finish, or as a final finish. The removal of both oil and dirt is usually involved, and oft-times metal swarf as well, and one of the most general methods of treatment utilises a hot solution of an alkaline compound. The purpose of such solutions is to emulsify mineral oils, to convert saponifiable oils into soaps, and, by mechanical action, to remove extraneous solid matter. Over a period of many years, several alkalis have been used alone or in combination, and numerous proprietary products have appeared with the object of endeavouring to incorporate the desirable properties of two or more of the common compounds. Of course, the most widely used alkali is caustic soda, but sodium carbonate, either as soda ash or washing-soda crystals, silicate of soda, and trisodium phosphate, all find considerable application. The introduction of many new alloys and metals, and their general commercial recognition, has caused a wider search for suitable alkalis, and particularly for those without undue action upon aluminium base alloys. Again, studies into the mechanism of alkali cleaning, the need for rendering it rapid and efficient, have given stimulus to attempts to formulate a universal cleaner more nearly approaching the ideal.

A number of criteria must characterise the ideal alkaline cleanser, and up to the present no one product fulfils these demands. The properties required include the following:—The compounded cleanser must be completely and easily soluble in water, and effective at as low a concentration as possible. The solution needs to be stable, not undergoing decomposition upon standing for a period, upon heating or aeration. It must be capable of immediately "wetting" work immersed in it. The chemicals contained in the solution must possess strong powers for emulsifying machine and other mineral oils, for saponifying the fatty oil constituents, and capacity for deflocculating other extraneous matter, such as dirt, paint contamination, soot, etc. Again, having removed this oily matter from the object, the solution must be capable of holding it virtually in solution or at least peptonised to a colloidal state. The solution should not attack the base metals concerned to their detriment with respect to appearance, dimensions or mechanical strength. Finally, the solution, or the steam rising from hot tanks, must not be irritant to operators.

The majority of metals of engineering, including steels, coppers, brasses, bronzes, and nickel silvers, are immune from any deleterious attack from alkaline solutions under the ordinary conditions obtaining. On the other hand, unless wise selection is made, trouble will be encountered with aluminium and aluminium base alloys, tin, tinplate, and soldered articles, and zinc, zinc-coated metals and zinc base alloys. The aluminium series of light metals are readily dissolved by caustic-soda solutions and quite rapidly by sodium carbonate solutions. Zinc and its alloys are likewise soluble in caustic soda, while they are blackened by sodium carbonate, and the film formed is difficult to dissolve off them. Soldered articles blacken rapidly over the soldered areas, and the solder disintegrates upon treatment in hot, strong caustic-soda solutions.

Under normal conditions of machining, drilling, tapping, milling, pressing and forming, a very wide range of cooling and lubricating media are employed. Aqueous emulsions of oil and soap, sulphurised cutting oils, tallow, tapping greases, and heavily loaded soap greases for deep drawing, as well as straight fixed or mineral oils, are encountered. Additionally, articles collect extraneous dirt and dust, as well as having adhering to them small particles of swarf and metallic dust. Taking this variety of conditions alongside the fact that components are generally of a range of base metal types, and again size and configuration will vary considerably, it can be seen that the problem is not as easy as would appear. Bearing in mind the miscellaneous nature of the articles with respect to size, handling of them has to be appropriately devised, to ensure efficient cleaning over their entire surfaces, especially with respect to holes and crevices. The object of the clean will affect decisions in this direction. Where only a reasonable cleanse for handling purposes is involved, treatment in baskets or on racks designed to suit the articles generally suffices, whereas, on the other hand, the perfect cleanse prior to electroplating may involve wiring.

The principal alkalis called upon for preparing degreasing solutions are caustic soda, sodium carbonate, sodium silicate, and trisodium phosphate. The first two are used in concentrations up to 1 lb. per gal. of water, the solutions being used boiling. The last two are less frequently employed alone, but more generally figure as ingredients in complex mixtures. Each of these materials has its advantages and disadvantages. Caustic soda possesses the maximum alkalinity, and this renders it the most efficient for the removal of fixed oils by saponification, but does not appreciably aid the emulsification of mineral oils or the peptonisation of solid dirt. Consequently, scum-forming propensities are high. Again, it is not free-rinsing, in fact it is the most difficult of the series to remove by subsequent washing. In general, these shortcomings are not overcome by increasing concentrations, and 2 oz. to 4 oz./gal. function as efficiently as 1 lb./gal. Purely from an initial cost aspect, caustic soda is the cheapest alkali. Sodium carbonate possesses one marked advantage over caustic soda in being far less irritant to operators, the troubles arising from the exposure of arms to spray or steam being practically eliminated. It wets the work a little more readily, and is a little more free-rinsing, but does not appreciably improve upon the other defects. The main purposes behind the introduction of sodium silicate and trisodium phosphate into metal degreasers are to rectify the deficiencies of the two simple alkalis with respect to wetting power, peptonising and emulsifying properties, and to aid free-rinsing. Sodium silicate seems to be the more preferable of the two, particularly with respect to peptonisation. Sodium meta silicate, which is procurable in the form of small solid lumps ($\text{Na}_2\text{SiO}_3 \cdot 5\text{H}_2\text{O}$), is one of the most convenient types to employ. It is not so virulent as caustic soda or sodium carbonate in promoting sores or irritation. It wets satisfactorily and washes off freely. Emulsifying character is good, and, moreover, it does not unduly depress the emulsifying action of small additions of soap (sodium oleate or resinate) which are frequently made. On the other hand, if it is called upon

to exercise much in the way of saponification, some tendency for silica to separate may occur, and this can form an undesirable film on the work. Using metasilicate, however, this objection is practically absent and is less marked than with higher silica content sodium silicates. Again, this film formation possibly refers to the use of this material as the sole ingredient of the solution, and it is eliminated by additions of caustic soda or of sodium carbonate.

pliers' recommendations for general purposes were 5% concentration and a working temperature of 60-70° C.

The material shown in Table II is in effect a combination of solvent and alkali degreasers. The alkali relied upon is the metasilicate, with soap an essential ingredient for the emulsification of the solvent constituent. Suppliers' recommendations were 4-5% concentration and 60° C. operating temperature.

TABLE I.
ANALYSES OF TYPICAL PROPRIETARY ALKALI CLEANERS.

	1.	2.	3.	4.	5.	6.	7.
Physical condition	Solid, Small Lumps.	Solid, Powder.	Solid, Powder.	Solid, Powder.	Solid, Powder.	Moist, Jelly.	Solid, Powder.
Composition, %—							
Caustic Soda	—	—	—	41.0	—	23.6	20.2
Sodium Carbonate (Soda Ash)	—	—	—	55.5	41.0	—	—
Sodium Silicate	58.7	54.1	—	—	26.1	8.5	31.7
Trisodium Phosphate	—	—	52.9	0.8	7.5	—	6.9
Glycerine	—	—	—	—	—	13.0	—
Soap (Sodium Oleate)	—	5.3	—	—	—	—	11.2
Water	41.3	40.6	47.1	1.8	25.4	54.9	30.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE II.
ANALYSIS OF LIQUID CLEANSER, SOLVENT/ALKALI EMULSION TYPE.
Composition %.

	%
Solvent	90.0
Sodium Silicate	5.2
Soap (Sodium Oleate)	4.8
	100.0

Solvent consisted of approximately two parts tetrachlorethane, one part water.

Tables I and II refer to a number of proprietary degreasers of the alkali group. Material No. 1 is a commercial sodium meta silicate, and the water content is that normally combined with the silicate. The suppliers' recommendations for general purposes degreasing, including aluminium and zinc base die-castings, were 2 to 3% concentration and 50°-80° C. for operating temperature. For work polished by buffing—e.g., nickel or copper prior to chromium-plating, the inclusion of 0.025% of sodium resinate soap is advocated to assist in emulsifying residual polishing compound left in pores of the metal.

Material No. 2 is a slightly modified sodium metasilicate in so far as it contains a portion of soap to improve emulsification.

Material No. 3 is commercially pure trisodium phosphate, the suppliers' instructions being to employ 2 oz. to 8 oz./gal. of water, short of boiling. Comments have already been made to the effect that this compound is not favoured so strongly as the metasilicate, No. 1.

Material No. 4 comprises approximately equal portions of caustic soda and sodium carbonate, with a small addition of triphosphate. The water content is mainly that entering with the caustic ingredient. There is nothing about this composition to specially recommend it.

Material No. 5 is a more balanced mixture. It excludes caustic soda, sodium carbonate being the prime degreaser, with liberal amounts of sodium silicate and phosphate to impart their beneficial influences on emulsification and peptonisation. Material No. 6 represents rather a unique composition of the caustic class, designed to improve wetting characteristics, and with sufficient sodium silicate to reveal effective peptonisation. The supplier's recommendations for practice were 5% concentration in water at boiling point, and special reference made to cleansing of waxy surfaces, removal of polishing compounds and such like.

Material No. 7 is a caustic-soda base, with generous proportions of both silicate and phosphate, and also a soap constituent to perfect the emulsification properties. Sup-

The values in the tables are expressed in such a manner that combined water (i.e., water of crystallisation) has been included in the item "water," and the silicate and phosphate contents therefore representing anhydrous forms of these salts. Also, the sodium silicate constituent throughout represents the metasilicate form.

Users of alkali degreasers are faced with a decision between the use of the older established caustic soda solutions, which are operated up to 20% strength or even greater, or the preparation of a carefully balanced mixture incorporating more expensive ingredients, or, again, the adoption of a proved proprietary compound. Caustic soda is the least expensive material, and the additional expense of the other types must be compensated for in some direction. In any case, where heavily contaminated work is to be treated, the bath is going to be rapidly contaminated, as there will be a limit to the quantity of oil and scum that can be held in emulsion or suspension. It is generally desirable, therefore, to use a strong caustic cleanse, when the base metal permits it, to remove the bulk of the grease and to employ a balanced mixture for a final treatment of the article. For those base materials which are attacked by strong alkalis, a simple trichlorethylene plant is recommended for the first cleanse. This removes the bulk of the oils, and leaves grease, dirt and swarf for the mild alkali treatment.

Since it is generally desirable for the user to have control over his own mixtures, since baths are easier to maintain by analysis and to replenish at economic periods, compounding of the cleanser on site is usually favoured. Perhaps the simplest and most efficient compound for shop preparation is a 50/50 mixture of sodium metasilicate crystals and soda ash. A good concentration for heavy duty is 4 oz. of each per gal. of water, and 2 oz. of each for light work when treated in open tanks. For use in continuous machines, the concentration will depend not only on the contamination of the work, but also on the design and mode of operation of the machine. Concentrations from 0.5 oz. to 1.0 oz. per gal. of each ingredient represent a typical range. The solutions mentioned can be used for magnesium and aluminium base alloys as well as the common metals of engineering, copper, brass, steel, etc. For the zinc base alloys, special procedures are resorted to, and electrolytic cleanses used wherever practicable, otherwise solvent cleanses. A typical cathodic process uses a solution containing 4½ oz. of trisodium phosphate and 1½ oz. of sodium meta silicate per gallon of water operated boiling. Immersion times are strictly kept to a minimum, and current density adjusted to just cause—free gassing over work

surfaces. Work is, then, thoroughly water-rinsed and pickled for a minimum immersion time (few seconds to a maximum of 1 min.) in cold 8% hydrochloric acid solution.

The silicate-carbonate cleaner recommended is an admirable one for the very light alkali degrease essential immediately prior to plating. The inclusion of soap in the mixture is not recommended for this class of clean, because nearly always the work passes through (1) alkali, (2) water, (3) acid pickle, (4) water, (5) plating vats. The presence of soap in (1) renders the possibility of a soap film passing over to the acid, (3) and therein precipitating traces of fat over the work, spoiling adhesion or covering of the plating thereby.

A brief reference to cleaning equipment will not be deemed out of place. The bulk of work will probably be handled manually through still tanks, and the ultimate efficiency of the solutions will be dependent upon design of the equipment and method of operating. The process as indicated above involves (a) rough clean, (b) cold wash, (c) hot wash, (d) final clean, (e) cold wash and (f) hot wash, and for best working equipment will be provided for all these, although if space enforces it (c) may be eliminated. Of course, for cleaning between machining operations (a), (b), and (c) suffice. The tanks should be so designed to provide ample space to accommodate baskets, racks, etc., and adequate heat supply, and fixed at a convenient operating height and with liquor level at least 8 in. below the top to facilitate draining back of the work. But tank size must not be disproportionately excessive, otherwise the problem of maintaining an adequate flow of water in washing tanks becomes uneconomic, while in the alkali ones, frequent replacement of smaller volumes is more efficient. The rough clean alkali tanks should be provided with an overflow device into which the surface layer of grease and scum can be propelled. In the wash tanks, water flow must be adequate, and so disposed to ensure thorough flushing through of the tanks. One useful way of achieving this is to fix a metal partition, curved along the top edge to assist overflow, closely adjacent to one end of the tank. At the opposite end of the tank a horizontal water-feed pipe parallel to the overflow feeds the surface of the wash water by spray from a series of perforations. The main water supply is brought in at the bottom of the tank.

Where large volumes of work have to be catered for, conveyerised washing machines can be justified by continuous and uninterrupted output. In principle, such a machine consists of a large tank from which the cleaning solution is forced by a motor-driven pump through a pipe system into a hood, whence it sprays on to the work passing through on a conveyer. The tank is arranged for convenient charging and cleaning out, while the solution returning to it for recirculation is strained by passage through screens. The solution is discharged into the hood through jets situated in predetermined positions, above, below and at sides, to ensure that every surface of the work gets impingement. They may be fixed or oscillating jets, but the essentials are to ensure large fan-shaped jets of liquor being sprayed at adequate pressure in such a manner that they do not baffle one another, and that the work during its complete travel is continuously washed from one angle or another with fresh liquid. Conveyer systems can be overhead or under the work, or both types may be incorporated in the same machine. Work may be placed or hung on, or contained in baskets.

Again, where it is objectionable to leave a film of weak alkali on the work, and this is usually the case, the same machine can be divided into three sections—viz., (1) alkali spray, (2) hot-water spray, and (3) hot-air drying.

As an example of what is involved, the following type of machine, alkali cleanse only, would deal with something of the order 1,000 lb.-hour of miscellaneous small articles contaminated with the usual machine-shop grease:—

Overall size	12 ft. long, 4 ft. 6 in. wide, 6 ft. high
Working space	18 in. wide, 15 in. high
Tank capacity	120 gals.
Temperature of tank	70–80° C.
Steam consumption	For initial heating, 175–200 lb. For maintaining, 25–50 lb. per hour
Steam pressure	80 lb./sq. in.
Alkali consumption	Of the order of 10 lb. per day
Conveyer speed	4 ft. per min.
„ motor	0.5 h.p.
Pump motor	3 h.p.

Alkali detergents have not by any means lost their position in engineering to solvent degreasers, and still offer certain advantages over the latter. When machines are employed, alkali degreasing plants are compact, neat and clean, and in contrast with the more massive automatic solvent cleaning machines. The latter also involve precautions and troubles with respect to the avoidance of solvent losses. On the other hand, the problem of alkali degreasing has by no means reached finality, and improvements in solution composition can be confidently expected in the future. For the present, universality of liquor composition is not a practicable proposition, and for still tank operation, a one-bath system is not always the most economic proposition. On the contrary, using automatic degreasing machines, alkalies show up at their best, operating at very low strengths, rapidly and economically.

New Metallurgical Base near Lake Onega

A MOUNTAIN of iron ore near Lake Onega, called Pudozhgora, is to become an important source of supply of iron and vanadium. A large plant is to be built for the production of high-grade pig iron and ferro-vanadium. The new plant will work on the titanium and magnetite ores at Pudozhgora, the reserves of which are estimated at 35 million tons. In addition to their vanadium content, the ores are marked by their purity and the almost complete absence of such harmful admixtures as sulphur and phosphorus. The building of this plant will be commenced early this year.

A feature of the Pudozhgora deposits is that they can be worked easily, because in many places the ore lies near the surface. It is estimated that open-cut mining can be carried on for some 16 years to supply a high-capacity plant.

New Metallurgical Works

THE Soviet authorities are drawing up plans for the construction of a metallurgical works in the town of Cherepovets. The new works, which will obtain its raw material from the ore deposits of the Lola Peninsula, is intended to supply metal to the industries of Leningrad, the Soviet Karelo-Finnish Republic and the Kola Peninsula.

Guide to Grinding Wheel Selection

A COMPLETE analysis of the conditions surrounding a given grinding operation is necessary before the solution of the proper grinding wheel can be made. This is largely due to the fact that some of the comparisons drawn in explanation of abrasive wheel action have tended to confuse rather than clarify the conditions under which an abrasive wheel gives satisfactory grinding action. In an analysis of a particular grinding operation, the various phases affecting wheel selection present themselves in the following order:—

1. Nature of material to be ground.
2. Type of grinding operation.
3. Methods and conditions surrounding the operation.
4. Abrasive wheel characteristics required to meet the above conditions.

The factors are discussed at some length in a 72-page booklet published by The Carborundum Company, Ltd., Trafford Park, Manchester, which also includes a list of suggested grinding wheels for a very wide range of work. This booklet contains much useful information on grinding as well as to the wheels used.

The Thermal Relation between Ingot and Mould

Paper No. 4/1940 of the Committee on the Heterogeneity of Steel Ingots, presented for discussion at the 1941 Annual General Meeting of the Iron and Steel Institute.

ONE of the terms of reference of the Stresses in Moulds Panel of the Ingot Moulds Sub-Committee—a Sub-Committee of the Heterogeneity of Steel Ingots and Open-Hearth Committees—reads as follows:—"To determine, if possible, the magnitude of the stresses developed in the wall of an ingot mould by a mathematical analysis of the temperature gradients and other conditions set up during and after casting the ingot."

Obviously, the first step must be to examine thoroughly known formulæ for temperature distribution in the mould. As a fairly large number of examples had already been worked out in the metallurgical laboratories of the English Steel Corporation, Mr. T. F. Russell obtained permission to prepare the present paper, which is submitted by the Stresses in Moulds Panel of the Ingot Moulds Sub-Committee for discussion at the 1941 Annual General Meeting of the Iron and Steel Institute. It is classified as Paper No. 4/1940 of the Committee on the Heterogeneity of Steel Ingots.

In his introduction Mr. Russell states that the determination of the exact mathematical relationship between the temperature distribution in an ingot and mould and the time which has elapsed since cooling commenced presents a problem of such complexity that it is safe to prophesy that many years must pass before any real advance is made on the present position of knowledge, established by the outstanding works of Saitô² and of Lightfoot.^{3, 5, 6, 7}

Perhaps the chief obstacle to further progress is the variation in the thermal diffusivity of a steel with temperature. Even if the exact functional relationship could be determined by such researches as those of Sub-Committee A, Thermal Treatment, of the Alloy Steels Research Committee on the thermal properties of steels, it would be extremely difficult, if not impossible, to deal with such functions in a mathematical treatment; up to the present time all theoretical investigations have presupposed a constant diffusivity.

There are many other factors, most of which are enumerated, which disturb the purely theoretical considerations dealt with in this paper and increase enormously the difficulty of finding more exact solutions than those developed by Saitô nearly twenty years ago. In fact, it can be confidently stated that, as long as casting procedure and pit practice are what they are to-day, a rigid mathematical solution will never be found, as the metallurgist is totally unable to state his problem to the mathematician.

Nevertheless, even such an apparently formidable array of disturbing influences should not deter us from examining thoroughly those formulæ which are based on theoretical assumptions at least approximating to practical conditions. It should then be possible to deduce some fundamental principles which can be compared with works experience, or to compare calculated time-temperature curves for certain points in a mould with experimental results. These comparisons may show that there is no satisfactory agreement between theory and practice, but at the same time they may show in which direction the disturbing

influences work, or even that the total effect of them is neglectable in certain cases.

The reason why known formulæ have not hitherto been thoroughly examined is undoubtedly that graphical determination of the roots of the equations given is not a satisfactory process and that an enormous amount of laborious work is required to interpret the formulæ arithmetically. The calculations were, however, facilitated by the use of a Monroe eight-figure calculating machine and the Mathematical Tables published by the British Association for the Advancement of Science, volume 1 containing circular functions and volume 6, part 1, Bessel functions of the order zero and unity.

The formulæ for the distribution of heat between ingot and mould which are examined quantitatively in this paper are essentially those developed by Saitô. Those for rectangular ingots and moulds have been modified by moving the origin of the axes of the co-ordinates from the corner of the mould to the centre of the ingot; this simplifies the arithmetical work and makes the formulæ more flexible. The formulæ given are based on the following assumptions:—

1. That there is no latent heat of solidification, or latent heat of phase changes in the solid state.

2. That the initial discussions do not alter, and the ingot and mould are in contact the whole time during the cooling of the ingot.

3. That the liquid steel in any horizontal layer is tranquil.

4. That heat transfer takes place parallel to one plane only, viz., a plane at right angles to the axis of the ingot, and there is no flow of heat across the axis.

5. That the molten metal is originally at a uniform temperature and the whole of the mould is at the temperature of the surroundings.

6. That the thermal diffusivities of molten metal, solid steel and the cast-iron mould material are equal to one another and independent of temperature.

7. That the temperature gradient at the surface of the mould is proportional to the difference in temperature between the mould surface and the surroundings.

The author discusses the practical variations, but expresses the view that the possibility of deriving more exact formulæ than Saitô's is very remote.

Examples are worked out for circular and square ingots of the same cross-sectional area cast into moulds of four different thicknesses. Curves are drawn showing the temperature at different points in the ingot and moulds, the temperature distribution across a diameter and the total quantities of heat in the ingot and mould at different times. Curves are also drawn to show the effect of "mould ratio" on the temperature cycle occurring in the ingot near to the mould wall and on the time taken for the temperature at the centre of an ingot to fall certain amounts representing solidification. The latter show that solidification is accelerated by increasing the mould thickness until the mould ratio is about 0.8–1.0, but that further increase in mould thickness has an inappreciable effect.

Four sets of experimental results on the measurement of mould temperature are examined, and they show that the greatest difference between theory and practice is found at positions in the mould near to the inner face. This is attributed to the effect of the air-gap forming between the ingot and the mould.

(2) S. Saitô, "On the Distribution of Temperature in Steel Ingots during Cooling," *Science Reports of the Tohoku Imperial University*, 1921, vol. 10, p. 305.

(3) S. M. H. Lightfoot, "The Effect of Latent Heat on the Solidification of Steel Ingots," *Journal of the Iron and Steel Institute*, 1929, No. 1, p. 364.

(5) S. M. H. Lightfoot, "The Solidification of Molten Steel," *Proceedings of the London Mathematical Society*, 1930, II, vol. 31, part 2, p. 97.

(6) S. M. H. Lightfoot, "Some Further Mathematical Considerations concerning the Cooling and Freezing of Steel Ingots," Fourth Report on the Heterogeneity of Steel Ingots, *Iron and Steel Institute*, 1932, Special Report No. 2, p. 162.

(7) S. M. H. Lightfoot, "Estimation of the Time of Separation of the Ingot from the Mould," Fifth Report on the Heterogeneity of Steel Ingots, *Iron and Steel Institute*, 1933, Special Report No. 4, p. 64.

Surface Defects in Semi-Finished Steel

Some Methods of Conditioning the Surface of Blooms, Billets and Slabs

Some of the causes of surface defects in steel are briefly reviewed and the methods used to prepare the surfaces of blooms, billets and slabs are discussed, particularly pneumatic chipping, mechanical chipping and scarfing. Attention is directed to the influence of heating on the surface quality of the rolled bloom and charts illustrate the relationship between time, temperature and surface quality in the soaking pit operation.

THE demand for high-grade steel has increased greatly in recent years, and the problem of quantity production encountered in steelworks has been modified to incorporate quality. In many industries there has been a continued demand to reduce the weight while at the same time to increase the strength of components. This trend towards the use of lighter parts, in nearly all cases, is at least partially obtained through the use of stronger steel. Stronger steel and harder steel are synonymous. Unfortunately, the harmful effects of surface defects are more likely to lead to early failure in the harder steel than in the softer steel. In the soft and mild steels, such as are used for buildings, bridges, shipbuilding, etc., unless ingot surface defects are of such magnitude that scrapping is warranted, there is very little need for extensive surface preparation. The soft and mild steels tend, during hot rolling, to weld, and therefore the effects of surface imperfection are greatly minimised. However, stronger steel requires higher carbon or alloy additions which quickly take the steel out of the hammer welding range. Thus, surface imperfections on ingots of stronger steel will not weld and must be removed.

Steel manufacturers are all familiar with the expense that is incurred in the preparation of semi-finished steel in the form of blooms, billets, or slabs. In many cases it is considered that there is a direct relationship in the service life of the finished part and the surface condition of the steel from which the part is made. The subject is considered at considerable length in a symposium, comprising four papers, presented before the American Iron and Steel Engineers' 1939 Convention, from which a number of salient features emanate.

A brief review of the causes of surface defects in steel is given by Spooner.¹ They may be classified as mechanical and metallurgical. Mechanical causes may be due to nicks from careless handling, deep scratches, roll marks, laps from guide marks or overfills, slivers from roll marks and nicks, or improper conditioning. Some of the metallurgical causes include overheating or burnt corners, ingot cracks, ingot scabs from splashes during teeming, poor surface due to metal hitting mould walls, ingot tears in early passes in the breakdown mill, mould action under the ingot skin, inherent corner weakness due to mould design, cracks due to improper heating and cooling, tearing due to improper rolling temperature, seams from inclusions just under the surface, and mould temperatures and cleanliness.

The amount of surface preparation of the steel depends entirely on the method of fabrication of the part and the final use of the steel. A bloom that would be satisfactory for re-rolling into a structural beam would require considerable conditioning if it were to be rolled into a round for the production of seamless tubing. Thus there are many standards to which the steel maker must work.

The methods generally used to prepare the surface of semi-finished steel are double heating, double conversion, pneumatic hammer chipping, mechanical chipping, grinding, scarfing, and peeling. In both operations of double heating and double conversion, at some point between the ingot and the desired size of bloom, the semi-rolled bloom is partially or wholly cooled, then reheated and rolled to the

desired size. The extra scaling developed by the second or the additional heating removes some of the surface defects. In the double heating operation no surface conditioning is carried out, while in the double conversion method the surface is conditioned by scarfing or chipping before reheating.

The cost incurred by these different methods of conditioning semi-finished steel varies over a considerable range, and figures cannot be quoted with any degree of assurance. As a comparison, the following percentages representative of preparation costs are given. The bar mill which furnished them produces mainly alloy steels and only a few grades of carbon steel for unusual services. The percentages are based on the average cost of pneumatic hammer chipping as 100%.

Double heating	25%
Double converting.....	105%
Hammer chipping (pneumatic)	100%
Mechanical chipping	60%
Scarfing	53%
Grinding	307%

Reference must also be made to surface cleaning. This is usually carried out so that the surface defects are more readily detected. The most common methods are the use of high-pressure water during rolling, flame descaling, pickling, or shot or sand blasting.

The method of conditioning employed by the steel producer depends upon the degree of surface perfection required and the grade of steel to be handled. In most cases grinding is a more costly operation than chipping, but, on a hard grade of steel, it may be more economical to grind than to chip. It is advantageous, in some instances, to adopt double heating or double converting to decrease subsequent surface conditioning. No set rule can be laid down as to the method of preparing the surface, since a number of factors must be considered.

Pneumatic Hammer Chipping

Like all other methods of surface conditioning, that of pneumatic power chipping is carried out to different degrees of perfection, being dependent on the desired surface of the final rolled product. With the development of mechanical chipping machines and scarfing procedure, the hammer chipping process is gradually being replaced by those methods which are more economical and more rapid.

In order to ensure the proper amount of chipping so as not to over-chip or under-chip, it is the practice of one plant to issue instructions to the chipper on each order being processed, according to the following code:—

1. All visible surface defects to be removed.
2. Permit light seams approximately 3 in. long.
3. Permit light seams approximately 6 in. long.
4. Remove scabs, tongue marks and deep cracks.
5. Remove no defects except for salvage.

A comparison of the tons chipped per man per chipping hour is not available for each of the various grades nor for the various chipping requirements. The costs of pneumatic hammer chipping vary as much as 1,000% in one plant, being dependent on the grade of steel and the area chipped, but some figures on the average of three different plants may serve as a guide:—

¹ A. P. Spooner, *Iron and Steel Eng.*, Vol. 27, No. 3, pp.22-5.

Plant	Tons per man per hour	Type of Steel rolled
A	0.3	Principally alloy.
B	0.7	Alloy and carbon.
C	1.2	Principally carbon.

Often, if an extremely good surface is required, steel is pickled prior to chipping. Pickling brings to light many slight surface defects which would not be seen if the scale had not been cleaned. It also shows up many slight surface indentations which are not defects, as well as defects of such size that would be scaled out in any subsequent reheating. The difference between harmful and unarmful conditions cannot readily be detected, and, as a consequence, when steel is pickled before it is chipped, much more chipping is carried out than is actually necessary to remove the surface defects, which may increase the cost of the chipping from 50% to 200%.

In carrying out the chipping operations, it is not only necessary to remove the surface defects but equally as important to flare out the chipping marks so that in further hot reduction the chipping grooves will not be the cause of seams or laps. To do this requires that the chipped grooves be at least twice as wide as they are deep.

Mechanical Chipping

A mechanical billet chipping machine is described by G. W. Lentz,² the most important feature of which is its extremely flexible tool head. With six cutting tools, operating at eight revolutions per minute, forty-eight cuts per minute are provided for the use of the skilled operator. With the use of a head having eight cutting tools operating at the same speed, sixty-four cuts per minute are possible. For certain types of work and material, cutting heads having ten tools, operating at speeds as high as eleven revolutions a minute, are now in use. This calls for great speed on the part of the operator in changing the position of the head, either forward, backward, up, or down, or combinations of these directional positions, since it provides for one hundred and ten cuts per minute.

This number of cuts per minute may seem extremely fast for viewing the effect of the previous cut, and for determining the necessity for further cleaning at one particular spot, but recordings have been taken where more than eight cuts per minute have been taken over a period of several consecutive minutes. This means that, exclusive of the carriage motion, in either direction, the operator was cutting into a bad spot, deep enough to warrant more than a minute being used for cleaning. It should be noted that the operator has a clear view of the work at all times and can regulate the depth of cut, exactly. This is very important, particularly when materials of high value are being chipped and where no method other than chipping can be used.

The part of this machine particularly responsible for the remarkable speed in removing defects is the joy-stick control, which eliminates much of the mental and physical work of the operator, it being only necessary to move the hand lever in the desired direction of cutting tool movement, to obtain the desired results. By moving the control lever to the left, the carriage is moved in that direction. Moving it to the right, moves the carriage to the right. Up and down movements result in corresponding movement of the tool head elevator. The tool head, being mounted in the movable housing in the carriage, follows in any direction. The tool head is designed for easy removal and replacement of the cutting tools.

Carriage speeds of 17 ft. per minute forward and 34 ft. per minute in the reverse direction are provided. The doubled carriage speed in reverse reduces the time loss during the period when the carriage is returned to the end of the billet after a new billet has been run in, or after one side has been cleaned and the next side has been turned up. Incidentally, the time required for releasing the billet clamps, turning the billet 90°, and again clamping it

firmly in cutting position is said to be less than 15 seconds. It is noteworthy that the billets are handled automatically after they have been reconditioned. A comparison by actual test of the relative cost of machine versus hand chipping shows a very substantial saving for mechanical chipping after taking into account all charges.

Scarfing

A newer method of cleaning semi-finished steel is discussed by G. D. Winlack³ in which blooms are deseamed by the oxy-acetylene torch, or what is commonly known as scarfing. Actually, scarfing is the process of burning out enough of the steel in the vicinity of a defect to ensure that the defect is removed and the surface of the steel left in such a condition that it can be rolled into satisfactory finished product. The method usually adopted is as follows:—

A specially designed and constructed deseaming torch is used which generally produces six oxy-acetylene flames. These are referred to as the preheating flames, and they raise the surface of the steel to a kindling temperature and maintain this temperature. Then a stream of dry oxygen, called cutting oxygen, is turned on and applied to the steel horizontally along the surface of the material by an experienced torch operator or scarfer. The cutting oxygen combines with the preheated steel and quickly removes a thin layer of material from the surface and in this manner the defect is removed, leaving good clean steel.

For a period after its introduction, the deseaming operation was only considered an auxiliary to hand chipping and only used on salvage or reclamation work for cleaning of badly cracked ingots, blooms and slabs, which otherwise were scrapped due to prohibitive chipping costs. The demand for large tonnages of conditioned slabs for the large capacity mills, together with customers' demands for practically over-night dispatch of their orders, overtaxed available chipping facilities, and steel producers turned to the scarfing operation, not only because this method facilitated the conditioning of the steel in large tonnages but also because the work was done economically. The operation is claimed to be ten to twelve times faster and at least 50% cheaper than pneumatic or hand chipping. The adoption of this method has increased so much in recent years that the tonnages now cleaned by scarfing far exceed that cleaned by chipping.

Torch scarfing ensures the removal of defects. Imperfections in the steel show up while the cut is in progress. The torch operator, through special goggles, sees the defects as irregularities in the cutting oxygen stream. Even the most minute defects are readily discernible by this method. Contrary to what is generally believed to take place, scarfing does not weld up small seams. The size of the material and the speed of the operation preclude any possibility of any welding action. The speed of operation—50 to 100 ft. per minute—also precludes any possibility of decarburisation. The scarfed surface is clean and bright and inspection is thus facilitated.

In order to take full advantage of the deseaming torch, careful consideration must be given to the layout used. Material, handling, preheating, inspection, reinspection, and gas supply should not be allowed to interfere with the torch operators. Fuel gases (oxygen and acetylene) should be piped from a central source of supply to the required number of operating stations conveniently located along the deseaming beds. Ample crane facilities for handling material to and from beds and for turning large sections is very important. In laying out scarfing beds, the placing of materials and direction of the deseaming should allow a number of torch operators, inspectors, helpers, etc., to work simultaneously without interfering with each other. Ingots, blooms, slabs and larger billets are generally scarfed while resting on low supports. While

² G. W. Lentz, *Iron and Steel Eng.*, Vol. 27, No. 3, pp. 26-8.

³ G. D. Winlack, *Iron and Steel Eng.*, Vol. 27, No. 4, pp. 44-54.

the operator is working on one bed, inspection, marking, material handling, etc., is being done on adjoining beds.

As will be appreciated, the removal of defective surfaces by the use of an oxy-acetylene scarfing torch from high carbon, alloy and tool steels involves some metallurgical factors, which, if not taken into account, will result in the failure of the operation. The rapid heating of the steel surface by the preheating flames and by the heat of the oxygen-iron reaction can cause a change in the structure at the surface with resultant hardness. The hardness developed is governed by the analysis of the steel and similar properties are present in the scarfed surface as would be developed by a hardening treatment. It is necessary to preheat the billet before scarfing. Pit annealing after rolling will not substitute for preheating before scarfing. Pit annealing will only ensure against transverse cracking of the steel when subjected to the high torch temperature, but not the lace curtain effect obtained after scarfing. At the present time preheating is the only insurance against "lace curtain" defects. Should the billet crack in a transverse direction, the strain set up in prior rollings has not been properly relieved by suitable cooling from the mill.

Pickling of scarfed steel should be carried out very cautiously, as the action of the acid coupled with the temperature of the pickling solution will attack the hardened area, developing an "alligator hide" type of defect on highly strained surfaces. On preheated billets this condition is eliminated as the scarfed surfaces are not in a highly strained condition. This method can be used, when in doubt, as a check to determine whether the steel was properly preheated.

The conditions surrounding the rolling mill heating furnace determine the proper procedure to be followed on the various analyses, in preparing the steel surface for scarfing for the mill. By proper handling of the steel for this mill, the steel will carry through the warming zone of the furnace and pass through the critical range of the steel into the austenitic state without any relief occurring. If it were possible to examine the surface structure at this time under the microscope, Winlack states there would be no difference noted from that of a chipped, ground, or machine chipped billet.

Relationship between Time, Temperature and Surface Quality

Surface quality of the rolled bloom is the main criterion used in determining whether the heating has been successful. Although the heating is not entirely responsible for the poor surface quality which sometimes occurs, Callinan and Soler¹ indicate that for a particular type of steel there is a range of time-temperature relationships which produce the best surface condition. The relationship between time, temperature and surface quality in the soaking pit operation is illustrated by a series of charts which are reproduced in the accompanying illustrations. Naturally, the condition of the steel as it reaches the pits has no small effect on surface quality, but except as otherwise noted the heats shown on these charts are those in which the furnace practice and pouring pit technique have been such as to produce satisfactory quality steel if processed properly in the pits.

All heats shown are the product of a soaking pit under complete automatic control and on which detailed and permanent records of the various items are available. The following are explanations of the terms used on these charts:—

In all cases the abscissa is tons of steel hand chipped per man hour and is indicative of the surface quality. Track time is the time from finish teeming of the last ingot of a heat to the finish of charging in the soaking pit. Pit time is the time from finish charge to start draw. Stabilising time requires more detailed definition. In this pit when the temperature reaches the desired control point the fuel input rate automatically decreases until it reaches

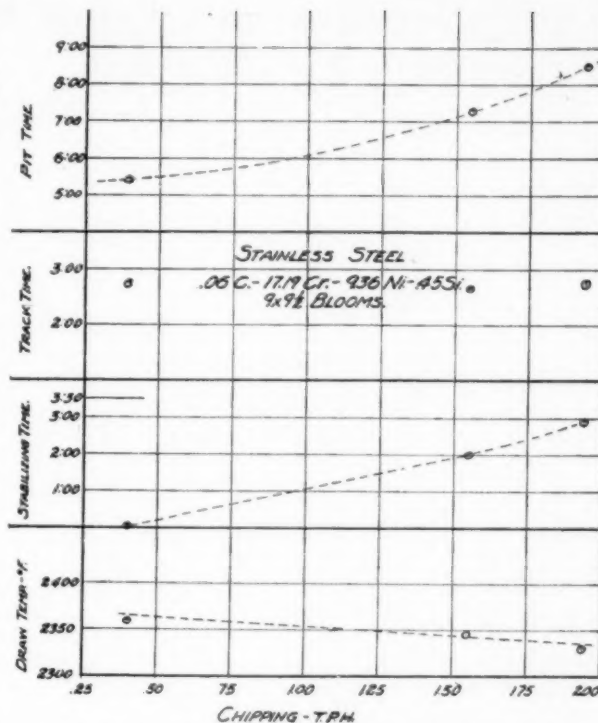
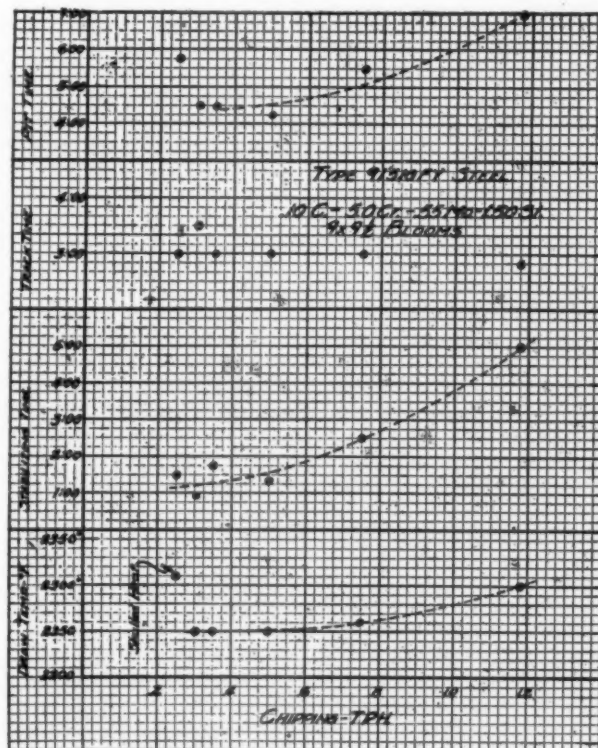


Fig. 1.—Three heats of 18-8 type stainless steel.

a certain minimum rate at which time the heat input is actually being used only to compensate for heat losses through the furnace structure and out of the stack. In this particular pit this fuel rate is from 1,100 to 1,300 cu. ft. per hour of 1050 B.th.u. natural gas. Stabilising time as used in these charts is the period from the time the fuel rate drops below 2,000 cu. ft. per hour to the time drawing was started.

Fig. 2.—Heats of a 5% chromium molybdenum steel.



¹ E. L. Callinan and G. Soler, *Iron and Steel Eng.*, Vol. 27, No. 5, pp. 48-57.

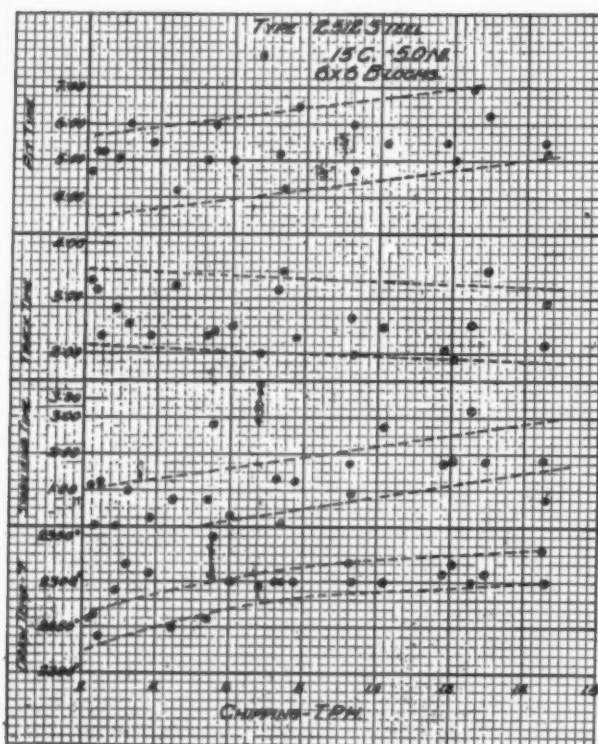
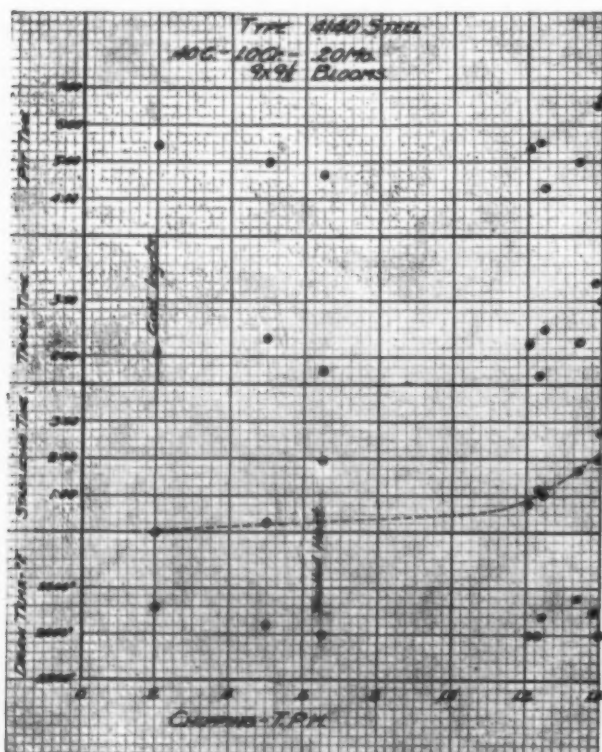


Fig. 3.—Several heats of a 5% nickel steel.

Fig 1 includes three heats of 18-8 type stainless steel. They were all made in exactly the same manner, tapped at the same temperature and teemed at the same rate. There is only 5 mins. variation in track time. In all cases the pit temperature at start of charge was between 1910° and 1930° F. Rate of fuel input varied slightly but all

Fig. 4.—Heats of a group of 1% chromium molybdenum steels.



were started off at medium low rates which were increased slightly in steps as the temperature increased, but which never reached the higher rates normally employed on low alloy content steels. The heat at the left side of the graph had the poorest surface condition in that it required the most chipping. Note that it had no stabilising time. It was heated to a higher temperature than the other heats, but there was no indication that it was overheated or burnt. The other two heats were heated to a lower temperature but had long stabilising times, indicating that they were thoroughly soaked. This chart brings out two important factors in the heating of this type of steel: (1) that even with the high alloy content extreme high temperatures are not necessary, and (2) the beneficial effect of soaking time.

Fig. 2 shows another type of alloy steel on which first efforts at heating were not too successful. Note that the heats at 2,250 and 2,260° F. did not produce a very satis-

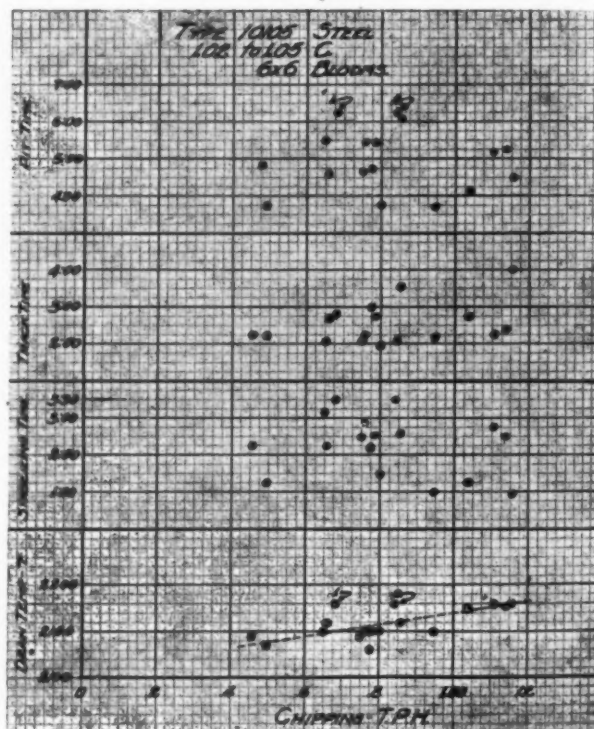


Fig. 5.—A number of heats of high carbon steel.

factory surfaces, even though they all had a fair stabilising time. Note also that at this temperature the surface improved with longer stabilising time. The heat having the best surface was heated at 2,300° F. and had an extra long stabilising time (this extra long time was due to a mill delay). The heat at the extreme left, having the poorest chipping, deserves an explanation. It had sufficient temperature and time but had a ladle skull and the ingots had a rough surface when charged into the pits. Evidently the poor surface cannot be blamed on the soaking pit.

Fig. 3 shows a greater number of heats than the previous one, and while a line curve cannot be drawn the trends of the heating factors are quite clear. Again it is seen that, as the temperatures increase and reach the range which their carbon contents predicts, the surface quality improves, and it also improves as the stabilisation time is increased.

Fig. 4 shows a group of steels in which the stabilising time appears to have a marked effect on the surface quality. Again it is noted that the skulled heat, even though it had ample time, produces poor surface, as did the heat that was charged cold and which has no stabilising time.

(Continued on page 93)

Production Methods for Case-Hardening

By A. J. Gibbs Smith.

Adaptation of the radiant tube principle makes possible an interesting development. A plant is described in which the whole process of casehardening is continuous and automatic. It is claimed that the method adopted gives a heat circulation of the furnace atmosphere which promotes uniformity of the carburised work.

IN American furnace practice, largely influenced by the achievements and the demands of the automobile industry, with its continuous production lines, there has always been a tendency towards the employment of the continuous type of furnace which can take its place in such a line. This is now becoming very marked even in the case of carburising, in spite of the difficulties presented by the process, and an interesting type of furnace has recently been installed in the works of a well-known car manufacturer in which the whole process is continuous and automatic, a throughput of over 1,000 lb. per hour being handled through all the stages by a single operator. This result is achieved by adopting the gas system of carburising in place of the box method, and by the convenient lay-out of the whole plant in the form of a rough square, as well as the incorporation of a complete system of oil-hydraulic pushers, interlocking doors, and suitable conveyers, the whole being under push-button control. The arrangement is shown in Fig. 1.

Carburising

In this plant either town gas or natural gas may be employed as a carburising medium. The latter is used in the plant under review. This is stated to give a particularly rapid rate of penetration without any deposit of soot on the surface of the work. In addition, the depth of case obtained by this method is stated to be more uniform than by the previous pack-hardening system, and distortion in the case of certain observed involute gears is reduced from an average of 0.0005 in. to 0.0001 in. by the new method. The atmosphere for carburising is approximately 300 cub. ft. per hour of natural gas, against a production of some 900 lb. of work. Means are provided for introducing such gas in easily controllable quantities both above and below the work.

Operation

The complete plant* is shown by the bird's eye view shown in Fig. 2, and its operation may be briefly summarised as follows: For carrying the work through the complete cycle light grid trays are employed and these are moved through the furnace by means of oil-hydraulic cylinders operating at a pressure of 500 lb. per sq. in. The oil valves and interlocking pilot valves are mechanically controlled, and these, together with interlocking switches, ensure that no fresh operation in the cycle can be undertaken until the preceding one is completed. The time cycle is controlled by an electrically operated device which permits of any desired time interval being set and maintained. Taking as an example the casehardening of gears in steel to the specification already cited, the trays each carrying some 300 lb. of work are loaded at the vestibule (1) shown in Fig. 1, at the rate of three per hour, and pushed through the carburising section by the first pusher. This particular section is divided into three temperature zones operating at 775°, 910°, and 915° C. respectively, and the passage of each tray occupies approximately seven hours. On arrival at the end of the section each tray is pushed sideways by the second pusher through a power-operated door into the cooling section, where it remains 1 hour 20 mins. during which time the work is cooled gradually to a final tempera-

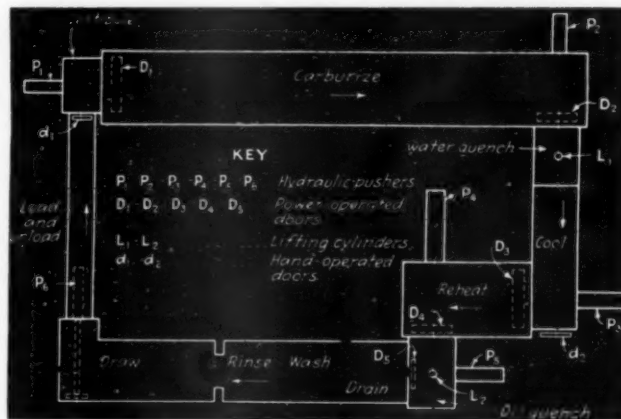


Fig. 1.—Layout of the continuous carburising plant.

ture of 315° C. (It should be mentioned in parenthesis that this portion of the shell of the furnace is provided at this point with a totally enclosed quenching tank equipped with the necessary operating gear, which permits of work being quenched at the end of the carburising section without intermediate cooling, if this should be desired.) The tray is then ejected by the pusher at point 3, past another door into the reheating section, where the work is raised to a temperature of some 795° C., taking 1 hour 20 mins. for the passage through. At the end of this section it is pushed on to an elevator and submerged in an oil-quenching tank, the contents of which are violently agitated.

The quenching process occupies about 20 mins., after which the tray of work is automatically elevated to the draining tray to allow the oil to drain off, and then pushed on to the washing and rinsing section, where the work is first subjected to a wash of strongly heated washing solution by means of high-pressure sprays, followed by hot water to remove all traces of the washing compound. The time occupied here is 1 hour 20 mins. The necessary temperature is maintained by the addition of hot waste

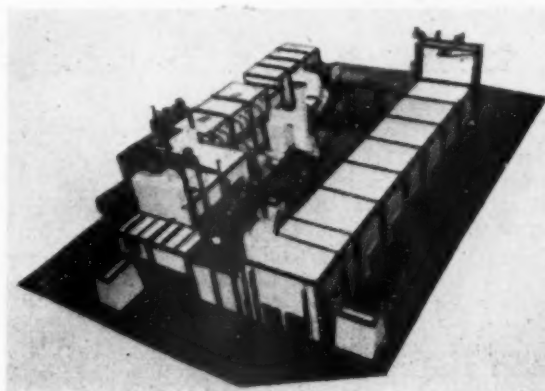


Fig. 2.—Bird's-eye view of the plant.

* The Continental Industrial Engineers Inc., of Chicago.

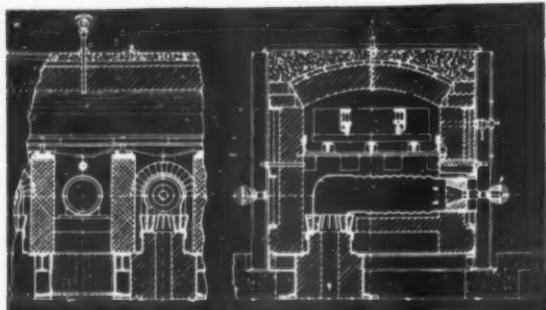


Fig. 3.—Sections of the carburising furnace, showing the heating arrangement and the manner in which the work is moved through the furnace.

products of combustion from the carburising and reheating sections.

At the other end of the drawing section the tray of work is pushed through the exit vestibule, which serves as an air-lock to prevent the entrance of free air into this section. It will be seen that the general arrangement in the form of a square brings the discharged trays back close to the operator, who has merely to unload the work on to a conveyer, which takes it to the inspection department.

Although a single operator handles the whole of the work put through the plant, the various sections are supervised by a laboratory assistant whose duty it is to take pyrometer readings, gas analyses, and to inspect the various safety devices.

Heating

This can also naturally be effected by either town gas or natural gas, although in the plant described the latter is used by means of high-pressure burners. In order to avoid the necessity for the employment of a muffle to

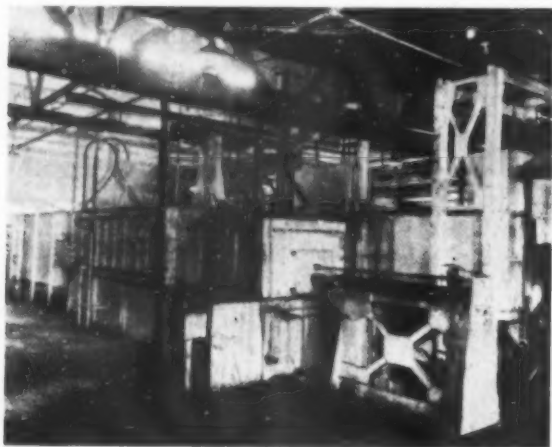


Fig. 4.—A view of the plant from the quenching corner.

prevent contact between gas flames and the carburising atmosphere, the makers of this type of furnace have employed a series of corrugated alloy-steel combustion chambers, each chamber being fired by a single burner, and evacuating the products of combustion downwards into a central flue running beneath the furnace. As the combustion chambers are located beneath the work, it follows that the lower portion of the furnace is maintained at a higher temperature than the upper portion, and a thermal circulation of the furnace atmosphere is thus obtained which increases the rate of heating and promotes uniformity of the carburised work.

Sternopal Dilutometer

MODERN cutting oils are designed to give optimum performance when used in accordance with instructions laid down by the manufacturers, who are naturally anxious to ensure the proper use of the cutting oils. This is especially true of water-soluble oils, which are used at varying strengths for specific purposes and where difficulties may arise when the solution is either too strong or too weak. Some manufacturers, such as Sternol, Ltd., stress the importance of correct mixing and correct proportioning, especially with regard to "Sternopal," which is based on entirely new principles and forms an intimate transparent solution with water in contrast to the older and conventional white emulsions. But the transparent nature of this solution makes it look thin, and there is a temptation to add more Sternopal to strengthen it up. This is very wasteful and the solution may prove unsatisfactory for the job in hand. Accidental dilution by water is another possibility which cannot be overlooked, so that maximum benefit can only be assured by exercising proper control of the concentration both in the mixing tank and at the machine. To facilitate this operation an instrument has been developed which can be used for routine control.

This instrument, known as the Sternopal Dilutometer, consists essentially of a flask with a long graduated neck, the graduations being marked off to indicate Sternopal dilutions:—80 to 1, 60 to 1, 40 to 1, 30 to 1, 20 to 1, etc. The principle of the test is the liberation of oil from the solution by the action of acid. The flask, together with a small funnel to facilitate filling, is supplied complete with ease. Particulars on application to the patentees, Technical Department, Sternol, Ltd., Royal London House, Finsbury Square, E.C. 2.

High-speed Tension Tests at Elevated Temperatures

VERY little is known, state Manjoine and Nadai,* about the actual forces required to deform copper, steel, or some of the other ductile metals at very high velocities of strain and at elevated temperatures. They describe a high-speed tension testing machine which was developed in which tension diagrams of metals were recorded. The test specimens occupied the axis of a copper coil, which acted as an induction furnace, in which temperatures up to 1,200° C. could be reached. The tension tests were carried out at an approximate constant relative velocity between the heads. Stress-strain curves were automatically recorded on the screen of the cathode-ray oscillograph, using the elastic strain in a very rigid steel bar as a means for the indication of the load and the relative movement of the heads of the specimens for determining the strains.

Surface Defects in Semi-Finished Steel

(Continued from page 88)

Fig. 5 shows a type of steel which is not difficult to heat. The only trend indicated is that best surface is obtained with the higher temperatures. The principle type of defects found in the steel are seams and scabs. These seams are believed to be due to excessive amounts of scale which gets rolled into the blooms. It is interesting to note on this graph that heats marked 1 and 2, although carried to the prepared temperature, were in the pit the longest time. This checks with the belief that excessive sealing (in this case produced by the long time) is detrimental. Evidently this type of steel should be heated rather rapidly to 2,180° F., given a 1 to 2 hour stabilisation, and then drawn as soon as possible before excessive sealing develops.

A careful study of the causes of surface defects and of the most economical methods of conditioning the surfaces of blooms, slabs and billets would be worthwhile to all concerned in the manufacture of steel.

* M. Manjoine and A. Nadai. Amer. Soc. T. Met. Preprint No. 44, 1940, 16pp.

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Metallic Lithium—Some Commercial Applications

By Stephen Coleman

Much research work on lithium has resulted in the application of this very lightweight element. It has been used as a hardener in lead and aluminium and their alloys. Reference is also made to an alloy of lithium and beryllium, which is claimed to be extremely light and to possess considerable hardness.

THE vaunted achievements of German industries have been rendered possible in many cases only by their ability to make use of past discoveries of British metallurgists. There is one metal, however, lithium, the uses and attributes of which have favoured their attention ahead of us.

Originally discovered as far back as 1817 by a Swede named Arfwedson, lithium is little known, but it has remarkable properties. There are four important ores from which the metal is extracted—amblygonite, an aluminium-lithium phosphate; spodumene, a lithium-aluminium silicate; triphylite, a complex double phosphate; and leopoldite, a lithium mica. This latter is found in Germany and Sweden; while the others are mined in small quantities in Brazil, America, Canada, Australia and Africa.

Some two or three years ago the Germans carried out extensive research work on lithium, and in the metallurgical laboratory of the Metallgesellschaft at Frankfurt a large plant was erected for the manufacture of industrial lithium carbonate and metallic lithium. They argued that their process was simple, but as a matter of fact it was complex. In treating the mineral substance for the extraction of lithium, a wet chemical process for the recovery of the lithium as carbonate was employed. Other salts of lithium were prepared from the carbonate. The reduction of lithium salts to metal was accomplished by electrolysis of the fused chloride in the presence of potassium chloride, but other salts, such as the bromide, cyanide and hydride were also used.

Channels of Employment

Having evolved a commercially successful process for the extraction of the metal from lithium mica, which they mine in their own country, experiments were advanced by German metallurgists and engineers to test the properties of this very light substance. It is the lightest of all solid bodies and has a specific gravity of 0.53.

It was found that the addition of a few hundredths per cent. of lithium gave a degree of hardness to lead and aluminium and their alloys which could not be attained in any other way. A series of lead alloys were discovered in which the added constituents were an alkali or alkaline earth metal or both, which could be used as efficient substitutes for lead-tin bearing metals. A small percentage of lithium added to lead alone was found to harden the lead sufficiently to form a good bearing metal. A lead alloy of this description, to which the name "Bahnmittel" was given, is used in Germany on the railways, and has met with such success on account of its hardness, duration and unique physical properties; its actual composition is lead-calcium-lithium.

Deoxidising and Purifying Agent

Research work by German metallurgists further discovered that lithium easily combines with the impurities of other metals, and consequently it has been used in Germany for purifying metals and improving their pro-

perties. Its capacity for taking up other elements is so great that in a molten condition it is able to abstract carbon, sulphur, phosphorus or occluded gases from alloys and metals. Another interesting feature about it is that, melting at 180° C., it forms an amalgam with mercury, which, in the combination LiHg, has a melting point of 609° C.

Mention must be made of the fact that the quantitative determination of lithium in an alloy containing only a few hundredths of the metal is exceedingly difficult, and this is believed to have been a hindrance to German research. It is noteworthy, however, that research has been in progress in America in connection with lithium. It has been found that the addition of small quantities of the metal to copper wire bars greatly improves the surface properties of the copper. As a deoxidising agent in the refining of copper, lithium has found a field of employment in the States. In contrast to the phosphorus often employed for deoxidisation, it has the advantage of not appreciably reducing the electrical conductivity of the copper.

An alloy of extreme lightness, permanence and considerable hardness has been produced in Germany containing both lithium and beryllium. The latter metal protects the lithium from oxidation by moisture or heat. Up to the start of hostilities no information was vouchsafed leading to the belief that extensive use had been made of this.

Notwithstanding Germany's supplies of aluminium which she obtains from her deposits of bauxite (of which she and France have big quantities), it is possible that lithium and alloys of this very light metal is being applied in connection with the construction of aeroplanes and other war supplies for which extreme lightness combined with reasonable strength is desirable. During their research work, they found that very small percentages of lithium conferred hardness and other good physical properties on aluminium, and an aluminium alloy containing lithium was used by them as a substitute for brass.

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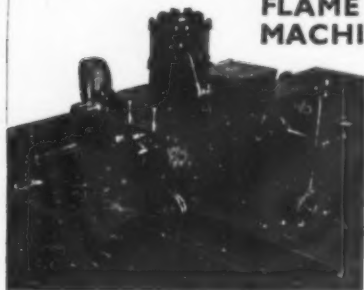
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